12.2020

SAVING THE GREAT LAKES

The irreplaceable, fragile ecosystem holds six quadrillion gallons of freshwater that our planet needs to survive

Beyond the Frame

#withGalaxy

In early 2020, the "**Beyond the Frame**" photo contest called on the @NatGeoYourShot Instagram community to share what inspires them. Two winners went on-location to Wyoming and Alaska to learn from National Geographic photographers and Samsung #TeamGalaxy Creators on how to shoot incredible imagery with a revolutionary camera—the Samsung Galaxy S20 Ultra 5G.

See how National Geographic's leading photographers and Samsung #TeamGalaxy Creators capture the essence of iconic locations.

▲ Photo: Jimmy Chin

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Alaska

▲ Photo: Katie Orlinsky

▲ Photo: Molly McCormick

▲ Photo: Jorden DeGaetano

Capturing Alaskan sled dog action

Alaska's Mat-Su Valley is a year-round hub for dog mushing, a sport that inspires National Geographic photographer Katie Orlinsky.

To capture off-season sled dog life using the Samsung Galaxy S20 Ultra 5G, Orlinsky partnered with Justin Savidis of Snowhook Adventure Guides of Alaska; Samsung #TeamGalaxy Creator Jorden DeGaetano; and Molly McCormick, Grand Prize winner in the "Beyond the Frame" photo contest.

The versatile Galaxy S20 Ultra 5G allows the photographers to experiment with composition and angles as the dogs bark and tug in anticipation of the day's run. For a fantastic still photo of a high-energy dog, DeGaetano uses the Galaxy S20 Ultra 5G 8K Video Snap to record 8K video, scrub the timeline, find the best moment, and snap the frame.

As Savidis mushes his team, the photographers capture images of the fast-moving dogs using the Galaxy S20 Ultra 5G Single Take AI (artificial intelligence), which takes 14 stills in 10 seconds with only one shot.

Arizona

▲ Photo: Kirsten Luce

▲ Photo: Erika Morillo

▲ Photo: Maxwell Loewenstein

Sunrise to sunset in Canyon de Chelly

Canyon de Chelly National Monument east of Chinle, Arizona, is an enchanting place. For National Geographic photographer Kirsten Luce, the ethereal beauty and ever-changing colors of the vast, sheer-walled canyon spark a sense of wonder.

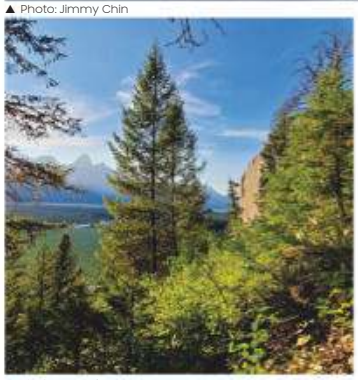
Awe-inspiring scenes can be captured from different perspectives using the Samsung Galaxy S20 Ultra 5G. Features like Shot Stabilizer—which negates a photographer's natural handshake and any need for a tripod—gives photographers the freedom to roam and shoot unburdened by extra gear.

The most-coveted shot is Spider Rock spire, towering over 700 feet above the canyon floor. Use the Galaxy S20 Ultra 5G Space Zoom feature for more defined, close-up views of the spire and the Ultra-Wide Lens to create a fuller picture of the canyon panorama.

▲ Photo: Brian Uchiyama

Wyoming

▲ Photo: Jimmy Chin



▲ Photo: Ty Anderson

▲ Photo: Laura Szanto

Epic rock climbing shots in Wyoming

Powerful natural forces shaped the serrated peaks of Wyoming's Grand Teton National Park, a favorite of National Geographic photographer Jimmy Chin.

Chin visited Blacktail Butte with Samsung #TeamGalaxy Creator Laura Szanto and Ty Anderson, a Grand Prize winner in the "Beyond the Frame" photo contest. Their mission: use the Samsung Galaxy S20 Ultra 5G to capture action shots of climber Savannah Cummins.

To mirror her climb, Chin rappels down the wall to hang alongside Cummins. He films the action using the Galaxy S20 Ultra 5G 8K Video Snap, then scrolls through the video to find, snap, and pull out a fantastic still photo. Anderson stays atop the butte, expanding his view with the Ultra-Wide Lens to capture a shot of Cummins on the wall backed by the Grand Tetons.

"Absolutely stunning," says Anderson, looking at the image. "It's inspiring to be so creative on the fly and to actually be able to put into fruition the things you'd like in the moment."

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CONTENTS

On the Cover
A storm moves over Lake Michigan in this view from the Empire Bluff Trail in Sleeping Bear Dunes National Lakeshore, near Empire, Michigan.
KEITH LADZINSKI

Joy is priceless.
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FEATURES

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NATIONAL GEOGRAPHIC SOCIETY
YEAR IN REVIEW

Responding to a Rapidly Changing World

OUR WORLD HAS CHANGED dramatically since I accepted the position as CEO of the National Geographic Society in January, having spent the past nine years as president of Colorado College. When we look back on 2020, organizations will be measured by how they reacted to two life-altering global events: the COVID-19 pandemic and the racial justice movement spurred by systemic racism and violence toward Black Americans. *National Geographic* has covered both extensively.

In response to the pandemic, the Society pivoted to focus its education programs on supporting teachers, parents, and students with learn-at-home resources, including a series connecting students with National Geographic explorers on all seven continents. To help educators design distance-learning resources, we gave grants to teachers in under-resourced communities disproportionately affected by the pandemic. And to ensure that news about COVID-19 was reported safely and included stories of marginalized communities, we launched a global emergency fund for journalists, financing more than 150 projects in over 50 countries.

At the same time, we accelerated the Society's efforts to identify, support, and elevate the work and voices of explorers—scientists, educators, and storytellers who are Black, Indigenous, and people of color. Though our community of grantees and educators has never been more diverse—in 2019, 62 percent of our grants were awarded to citizens of countries other than the United States, and almost 50 percent were awarded to women—we have more to do.

In July we announced a diverse group of new storytelling fellows, whose projects include documenting Indigenous women's resistance against the exploitation of natural resources and telling the stories of those who lost a family member to gun violence. To curate the projects that focus on Black Americans, we've enlisted the help of C. Daniel Dawson, an adjunct professor at Columbia University. We've also partnered with National Geographic's television networks to promote diversity and inclusion in television production with our Field Ready Program.

We can only achieve our mission to illuminate and protect the wonder of our world when people of every race, identity, experience, and ability have a role in our work. With that goal, we enter 2021 as a stronger organization, positioned for excellence and relevance in a rapidly changing world. Throughout my career I have pursued organizations that share my values—a commitment to mission, boldness, transformative education, and dedication to advancing meaningful change. I'm honored to lead this institution and am grateful for your continued support. ▯

Jill Tiefenthaler, CEO, National Geographic Society

PHOTO: MARK THIESSEN, NGM STAFF

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THE GREAT LAKES

Valuing the Lakes (From a Distance)

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **KEITH LADZINSKI**

Youngsters play in Lake Michigan near the lighthouse in Michigan City, Indiana. The five Great Lakes have borders with eight U.S. states—Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin—and one Canadian province, Ontario.

I GREW UP in the Great Lakes State, and for many years now, during my annual summer (yes, it has to be summer) visit back to Michigan, I'm always happy about what I don't see. I don't see throngs of Californians (sorry) swarming adorable lakeside towns like Petoskey or Glen Arbor. I don't see hordes of New Yorkers (sorry) splashing about Lake Michigan or thundering down the steep white sands of Sleeping Bear Dunes.

No offense to the multitudes on both coasts, but I've always been glad the still-unspoiled charms of northwest Michigan felt like my secret—or at least a secret held by a smaller group of people, largely from the Midwest.

Lately, however, I've been thinking about the downside of being out of sight and out of mind.

Most people seldom think about Lakes Michigan, Huron, Superior, Erie, and Ontario. Many can't even name all five. But they should care about them because, as Tim Folger writes in this month's cover story, the Great Lakes are "arguably the continent's most precious resource, incalculably more valuable than oil, gas, or coal."

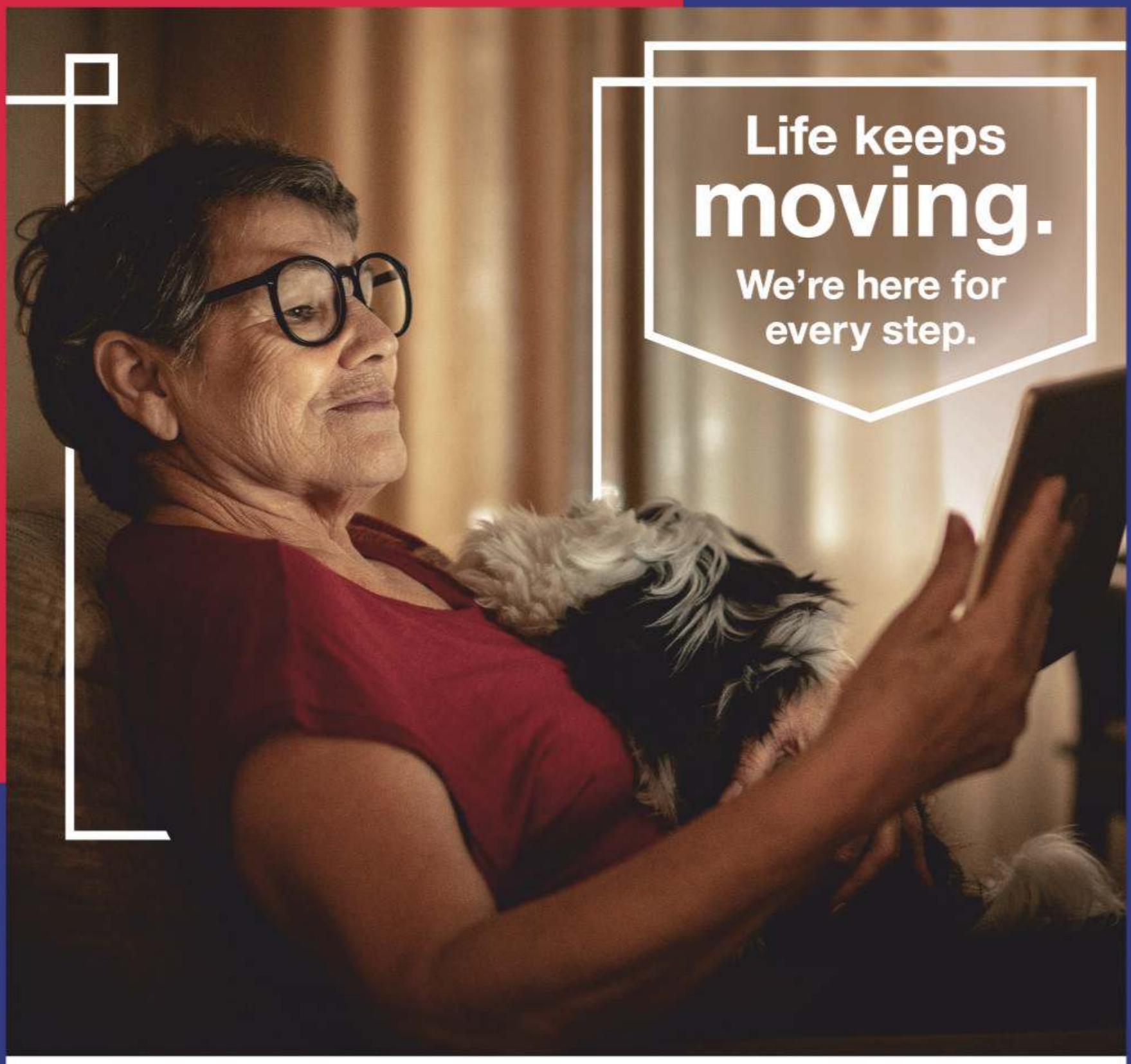
Together the lakes hold more than 20 percent of the surface freshwater on Earth and 84 percent of the surface freshwater in North America. Almost 40 million Americans and Canadians "drink from the lakes, fish on them, transport goods over them, farm their shores, and work in cities that wouldn't exist" without them, Folger writes.

And yet we abuse them terribly: polluting them, introducing invasive species, allowing fertilizer runoff to create algal blooms large enough that they can be seen from space. Climate change means the lakes don't freeze as much as they used to, and severe storms have become more frequent.

Everywhere you look on Earth, there are big problems. Fires out of control on the U.S. West Coast and, shockingly, in the Siberian Arctic. Melting ice in Antarctica and melting glaciers in the Himalaya. The careless destruction of the Amazonian rainforest. You hear a lot about these problems in *National Geographic* and in other media. But we hear less about what's happening to the Great Lakes: the irreplaceable, fragile ecosystem of six quadrillion gallons of freshwater that our planet needs to survive.

So read Folger's story. Appreciate the beauty of the landscape in the stunning photos by Keith Ladzinski. Become an advocate to protect our Great Lakes. (But please, don't visit.)

Thank you for reading *National Geographic*.



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NATIONAL GEOGRAPHIC

VOL. 238 NO. 6

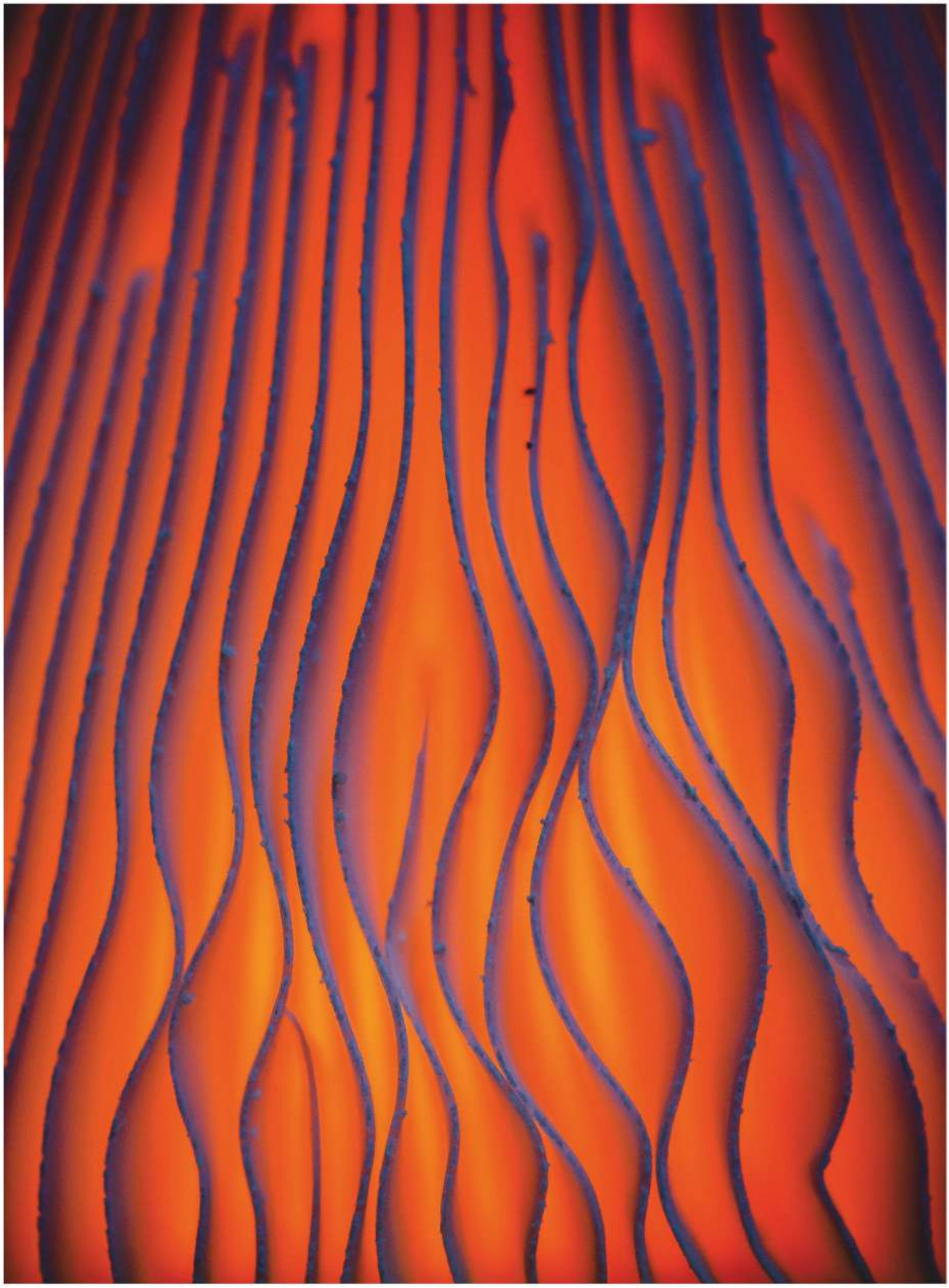
AS SEEN FROM THE GROUND

STORY AND PHOTOGRAPHS BY **JAN VERMEER**

Quarantined in the Veluwe region of the Netherlands, a photographer studies the fungi in his garden and nearby woods.

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE

One of the best-known wild mushroom species, the fly agaric *(Amanita muscaria)* is the photographer's favorite, and he was delighted to find it growing in his yard and his neighbor's.



When light falls through the cap of the fly agaric mushroom, the underside's intricate pattern takes on a vibrant glow. The species is known to be poisonous and psychoactive.

This small purple fungus, *Ramariopsis pulchella,* was growing in Gelderland Province on the Dutch-German border. European conservation groups are monitoring it as possibly threatened.

To mate, a *Schizophyllum commune* mushroom need only bump its fibrous mycelium against another so cells connect. This species can have tens of thousands of mating types and can reproduce with compatible ones.

THE BACKSTORY

FUNGI ARE GOOD INDICATORS OF THE STATE OF A FOREST: WHEN THEY FLOURISH, SO DO MANY OTHER LIFE-FORMS.

I'VE TRAVELED all over the world taking pictures of nature and ecosystems. When COVID-19 hit in March 2020 in the Netherlands, where I live, I stayed home like everyone else. That's when I began to notice the fungi growing in my yard and around my neighborhood.

That mushrooms and other fungi thrive in humidity became abundantly clear to me starting in autumn 2019, when the Netherlands received an exceptional amount of precipitation.

But perhaps more essential than humidity for fungi is dead wood. Rotting timber contains nutrients that enter the soil, which in turn can help microorganisms, fungi, and insects. The entire food chain benefits from it. Around here, deposits of wood left behind from a former era of forest-cutting have long enriched the soil and supported biodiversity.

The situation may be changing. For fire prevention, twigs, branches, and trees—material that can be food for mushrooms—is being thinned from some Dutch forests. With the rise of power plants that run on biomass, that material can be turned into energy. But if there are disruptions of the woodland cycle in which rotting matter creates new soil, this could reduce the diversity of fungi and have ripple effects across the ecosystem.

In my yard, I've watched the various fungi grow and change with the seasons. My favorites are fly agaric mushrooms, with white stalks and bright red tops. I was delighted to discover the polka-dotted fungus, but my neighbor had even nicer looking ones. I asked him if he would mow around them when he cut his grass, so I could make an image—the one that opens this article.

With fewer fungi, a forest would be less rich ecologically—and more boring. So I'm always looking forward to the damp of autumn, to see how the organisms will grow back. ▯

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NATIONAL GEOGRAPHIC | VOL. 238 NO. 6

Celebrating in the Pandemic

WE'RE MISSING HOLIDAY CLOSENESS JUST WHEN WE NEED IT MOST. BUT EVEN GRIM, UNCERTAIN TIMES HOLD SPARKS OF LOVE AND LIGHT.

BY **ANNE LAMOTT**

SOMETIMES WE LET GO of things, sometimes things are taken away, and sometimes things break, such as lives, hearts, entire ways of life. Doesn't our world feel broken in the time of COVID-19, maybe especially when holy days arrive?

If we are wise, we avoid large gatherings, dinner indoors with family and old friends, services at our mosques, temples, churches—so we lose the joyful and profound rituals and gatherings at this time of devastation when we need them most. But does this mean we lose the nurture, bonding, and sacred silliness that ceremonies provide?

Maybe we can be fully immersed in the holy even as we keep ourselves and our beloveds safe. Maybe broken isn't the end of the world. Maybe broken is a new beginning, a portal.

Let's start with what we mean by "holy."

The word derives from whole, uninjured, healthy, complete. I am not always feeling whole these days.

I MADE ALTARS AROUND THE HOUSE: FEATHERS TO REMIND US OF FLIGHT, WEIGHTLESSNESS, GRACE; SOMETHING FROM THE BEACH THAT HAS BEEN TOSSED AND CHURNED, BROUGHT TO BEAUTY BY TURBULENCE.

Rather, I am often rattled, sad, mad, existentially tired, and crunchy. I would love a nice burning bush about now—but the holy doesn't come only from the divine, as I understand it. It's woven through life.

The holy is not a spectacle, the Rockettes on stage at the Taj Mahal backed by the Mormon Tabernacle Choir. It is more often felt in small graces and blessings, although you do have to be paying attention to catch the momentousness of the moment. That's the rub. It is around us, above us, below us, and inside us all the time. It's here, but often we're not.

Maybe our definition of holy and whole have to change. The early morning is holy. Holy is the warmth of the grocer or grandchild, or a bowl of homegrown tomatoes from the neighbor who once reported you on Nextdoor. I'm whole, -ish, older, slower, with a few dings.

Holy are the candles of the menorah or carolers, or a community bonfire. These days are about the coming of the light—warmth, illumination, life anew. The triumph of light over darkness, as in the Persian tradition of Yalda: gathering with loved ones by candlelight and firelight, reading poetry and telling stories—and the inevitable sacrament of eating special foods—to celebrate the longest night of the year. It's called "the night of birth." We are there now. It's beautiful, and hard, as life so often is. Suffering is part of the beauty of the human drama. (I hate that.)

FINDING WHAT IS SACRED amid the loss might look like a wild spiritual awakening. It might be a secular return to the rituals your people have been performing for millennia—our peeps always did it, let's do it too—or new DIY rites your loved ones create. (Sparklers, s'mores, and formal wear?)

All of these offer connection with the larger, truer world, with the ancient, with timelessness and the luminous now. Rituals fill our souls and tummies. They distract, refocus, enliven.

But what if there's only you and a few others, a couple of whom exhaust you?

Everything—our whole system of life, family, travel—has ground to a halt. So if broken is what we've got, where do we begin the repairs?

One possible solution is how the ancient Japanese repaired broken pottery with gold along the mended spots. You dishonor things if you won't admit they are broken. You value them by repairing them. The gold edging adds to the broken things' beauty. You adorn the cracks so now they really show. (And as Leonard Cohen reminds us, that's how the light gets in.)

The world is broken. What is the gold?

On the visible level, the gold is appreciation that comes from paying attention with gratitude to what is left: We praise the big things, the gifts of life, love, nature. But don't forget nice windows, your books, the curated strew of stuff that hooks us into memories and people. I raise my eyes not only to the mountains and stars but to my living room beams, to the view

Pocket shrines: Little devotional items, long history

For centuries, huge shrines have been built out of devotion to a great love (think Taj Mahal) or a religion—and in the same spirit, people around the globe have created miniature versions. These "pocket shrines" were often carried by troops; many of the ones from both world wars are still around. Most consist of a tiny vessel—leather or cloth case, wood or metal capsule, even a bullet casing—sheltering a statuette or image. Today pocket shrines may be fashioned in matchboxes and dedicated to many faiths. Counselor Karla Helbert, who uses the shrines in grief and healing therapy, says they're helpful "to maintain a needed connection with your loved one, or to create a sacred space for remembering or engaging in any type of personal ritual." **–PATRICIA EDMONDS**

ILLUSTRATION: ELENI KALORKOTI

outside the windows. I savor the fresh air when I open them; it's the breath of the house. All these expand me. And I savor Oreos instead of the double chocolate death cake Becca brings to holidays.

Still, I long for my beloved communities, my family, the singing and sacred silence of church, the motley crowd of people who've joined us for dinner forever. I'm homesick for touch. I miss celebrations, good vibrations in the midst of grim times, and even loud celebratory noises. Loud noises scare off bad spirits. More than anything, I miss skin.

But we cannot fly anywhere or even drive to our cousin's hunting lodge or mobile home.

Left to my own devices, I am steeped in dread. But I am not left to my own devices: I have friends and an imagination. Since COVID-19, I first imagined us as our own planets. We could holy up our homes, with our cranky selves and those we're quarantined with, who can wear on our last nerve. (I am not going to name names.) But that was too large a canvas for me in my current condition. So I imagined my home as one of those glittery matchboxes friends have given me over the years, with Mother Mary on the cover, or Frida Kahlo, containing emblems of hope and faith: packets of healing dirt from Chimayo, an origami crane, a spray of dried bluebells, a heart.

Then I made altars around the house. Feathers to remind us of flight, weightlessness, grace. A mini scroll with one line of scripture, from Woodstock-era peace activist Wavy Gravy: "Dare to struggle, dare to grin." And something from the beach that has been tossed and churned, brought to beauty by turbulence.

We can make an altar on the island in the kitchen—which, if you're like me, is where we find ourselves most often—or in an actual portable matchbox.

LIFE WANTS TO KEEP reminding us of its sacred self, but we have to open our eyes and hearts. Yes, our hair looks like hell, and we're out of shape, and dislike our mate, and shouldn't have had children, but God, what a sunset. And I so appreciate the roof over my head. There is an exuberant patch of poppies and weeds outside in the rocky dirt. The poppies are lanterns: light over darkness, good over evil. Light your lantern with self-love. Shine.

We can't feel many people's warm skin, but we have the scarf that Emmy knit, the cap Granddad left us, our first toolbox that an uncle assembled for our eighth birthday even though we were a girl. These are as sacred as the statues and tapestries we would see in mosques, temples, Zendos, ashrams. We leave them around, to remember love.

It goes without saying that we put up photos of the people we love and miss: The connection is so deep, deeper than the physical, and contact, so much deeper than on the plane of talk. It is in the fullness of spirit, the capillary system, the ether of breath and memories. It also goes without saying that we play our holy music—hymns, *kirtans,* klezmer, Aretha—or listen to a wind chime, breezes made visible.

Then—drumroll—we pick up the phone, or log on to Zoom, and by prearrangement, on Kwanzaa, New Year's Eve, as Shabbat starts, or the solstice, we reach out. We say, "Hey, you!" As we used to bring our best selves to weddings and funerals, we bring them now to what we can still attend, by phone, or by walks in the neighborhood, masked, waving.

WHATEVER THE REALM, there can be a sense of direct transmission. Life has taken away some of the barbed wire of our emotional difficulties—yay—and we appreciate what is left. We make eye contact with each other, and this allows us to cry together; our eyes aligned: That is a lot of intimacy. The sound of each other's voices, the IV infusion to each other through the port in our chest when our hearts are open.

I have my body, where I live, the place of function, pleasure, pain, rest. I offer myself what I would offer a stranger: a hot bath, a plum, kind words.

The meaning of this pandemic is that we are all vulnerable and connected. We are in this together, spanning the globe, Buddhists, Jews, Muslims, Hindus, pagans, Christians, atheists. This is so much bigger than the virus, because love and caring are bigger than anything—even, or especially, suffering. These nudge the virus right out of the lane, here and there, creating spaces we can slip right through.

Even when we are lonely, hollow, heartbroken, or angry, we can slip through these gaps into what we have always longed for: presence, not presents. And that will sustain us, let us rejoice and be fed, until we can be together again. □

Anne Lamott is the author of numerous *New York Times* bestsellers, including *Hallelujah Anyway; Small Victories; Stitches;* and *Help, Thanks, Wow.* Her new book, *Dusk Night Dawn: On Revival and Courage,* will be published in March. A past recipient of a Guggenheim Fellowship and an inductee to the California Hall of Fame, Lamott lives in Northern California.

THE MEANING OF THIS PANDEMIC IS THAT WE ARE ALL VULNERABLE AND CONNECTED. THIS IS SO MUCH BIGGER THAN THE VIRUS, BECAUSE LOVE AND CARING ARE BIGGER THAN ANYTHING—EVEN, OR ESPECIALLY, SUFFERING.

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Although the campaign has now come to an end, our commitment never will. Canon will continue to be there for photographers and to support the ideals of biodiversity and coexistence in our world. Once again, thank you for sharing 39 unforgettable years.

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INNOVATOR

KATY CROFF BELL

BY **ANNIE ROTH** PHOTOGRAPH BY **REBECCA HALE**

This oceanographer deploys technology, diversity in exploration.

Most of the deep sea, Earth's largest habitat, has yet to be explored. Even after decades of probing and scanning the depths with submarines and remotely operated vehicles, scientists have seen just a fraction of what's down there.

In those uncharted waters Katy Croff Bell sees a great opportunity to engage women and people of color in science.

A National Geographic Society fellow and an expert on the deep sea (below 200 meters), Bell has been on more than 40 oceanographic and archaeological expeditions since 1999. When she began, there were few women in the field.

"If we're actually going to explore the entire ocean, we not only need new technology but also new communities of people to be involved," Bell says. She has built a diverse coalition of deep-sea explorers and students, and has developed ways to make the area more accessible to them.

New robotic and "telepresence" technologies have allowed Bell and others to make significant discoveries in recent years. In 2019 students monitoring deep-sea cameras in a collaboration with National Geographic's Exploration Technology Lab were the first to document the presence of cow sharks in the Galápagos Islands.

Those students aren't the only ones joining Bell in the deep sea. By deploying cameras in the depths and livestreaming her expeditions, Bell lets thousands of people around the world explore the ocean with her.

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DISPATCHES
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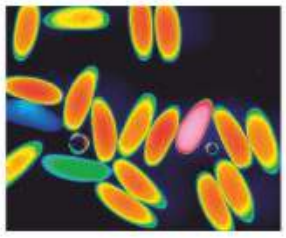
Tidying Up in Fly Cells

New research has identified a critical enzyme in fruit flies that destroys proteins inherited from the mother as the developing embryos (right) start to make their own. Researchers named the decluttering enzyme Marie Kondo, after the Japanese tidying guru who helps people discard things that no longer bring them joy. –JS



CONSERVATION

Hail, snail: New species discovered

For the first time in 60 years, scientists have identified a new native land snail species in Hawaii. Among Earth's most threatened animals, land snails and slugs account for 40 percent of known animal species extinctions since 1500. Hawaii has lost snails to invasive predators and reduced habitat. Finding the striped-shelled Oahu tree snail *Auriculella gagneorum* is a glimmer of hope for these natural recyclers and the conservationists working to protect them. –JS

AGRICULTURAL TECHNOLOGY

POLLEN SPECIAL DELIVERY

DECLINE OF INSECTS LEADS SCIENTISTS TO EYE NEW WAYS TO POLLINATE PLANTS. ONE IDEA: DRONES

AS POPULATIONS OF BEES and other natural pollinators diminish around the world, scientists are experimenting with high-tech replacements. One early attempt by a Japanese research group was a sticky-bottomed drone that could carry pollen among flowers just as a flying insect would—but when the propellers got too close, they damaged the plants. Now the same group has equipped drones with sprayers that release pollen-laden soap bubbles from a distance. In tests, pollinating pear trees with bubbles produced fruit almost as effectively as hand-pollinating (sometimes used to boost fruit trees' yield). Some ecologists say that such high-tech efforts are misguided and distract from the more important need to conserve bees and other threatened pollinators. For now, the research group is forging ahead: Next steps include developing a more biodegradable soap solution for minimal environmental impact and improving the drone's bubble-spraying accuracy. –JORDAN SALAMA

PHOTOS (FROM TOP): MICHAEL ZAVORTINK, RISSLAND LAB, UNIVERSITY OF COLORADO SCHOOL OF MEDICINE; EIJIRO MIYAKO; NORINE W. YEUNG

SABER-TOOTHED GIANT

BY **FERNANDO G. BAPTISTA** AND **PATRICIA HEALY**

In the South American savanna of the Pleistocene epoch, the saber-toothed big cat *Smilodon* survived by ambushing resident megafauna. A fossilized skull from Uruguay shows that some *Smilodon* were giants. It's not clear if this cat hunted solo or in a pack—but studies reveal that its bite, bone structure, and limb strength made it a formidable predator.

MEGA-CAT

In North America, the jaguar-size *Smilodon gracilis* was found mostly in what is now Florida and Pennsylvania; the slightly larger *S. fatalis* is best known from tar pit fossil beds in California. Those two species and the larger *S. populator* all roamed South America.

Modern human

Late Pleistocene human 5.25 ft, 143 lbs

Actual size of largest skull found

The Pleistocene closed with mega-fauna's extinction and the arrival of a new apex predator: humans.

LION

Panthera leo

A male modern lion can reach 550 pounds, a female 400 pounds.

SABERTOOTH

Smilodon populator

This reconstruction is based on the largest skull found; it suggests a 960-pound cat.

Hind limbs lower than forelimbs make back slope like a hyena's.

Shoulder height 3.3 ft

Pelvis

Shoulder height 4.3 ft

Average 4 ft

Long tails help lions and cheetahs balance at a run. *Smilodon's* bobtail is another clue that it hunted by ambush.

Humerus

65° to 70°

Section bones relative scale

Cortical bone

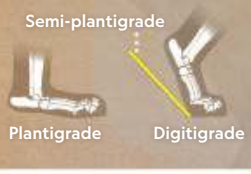
Short metatarsals

Walking angle

Wrists adapted for stability and strength helped the big cat in grappling prey.

SHORT HIND LIMB

Like many big cats, it walked on its toes (aka digitigrade). But to bear its great weight, strong hind limbs were shorter and foot bones less vertical.



As foot bones are closer to the ground than in other digitigrades, some label it semi-plantigrade.

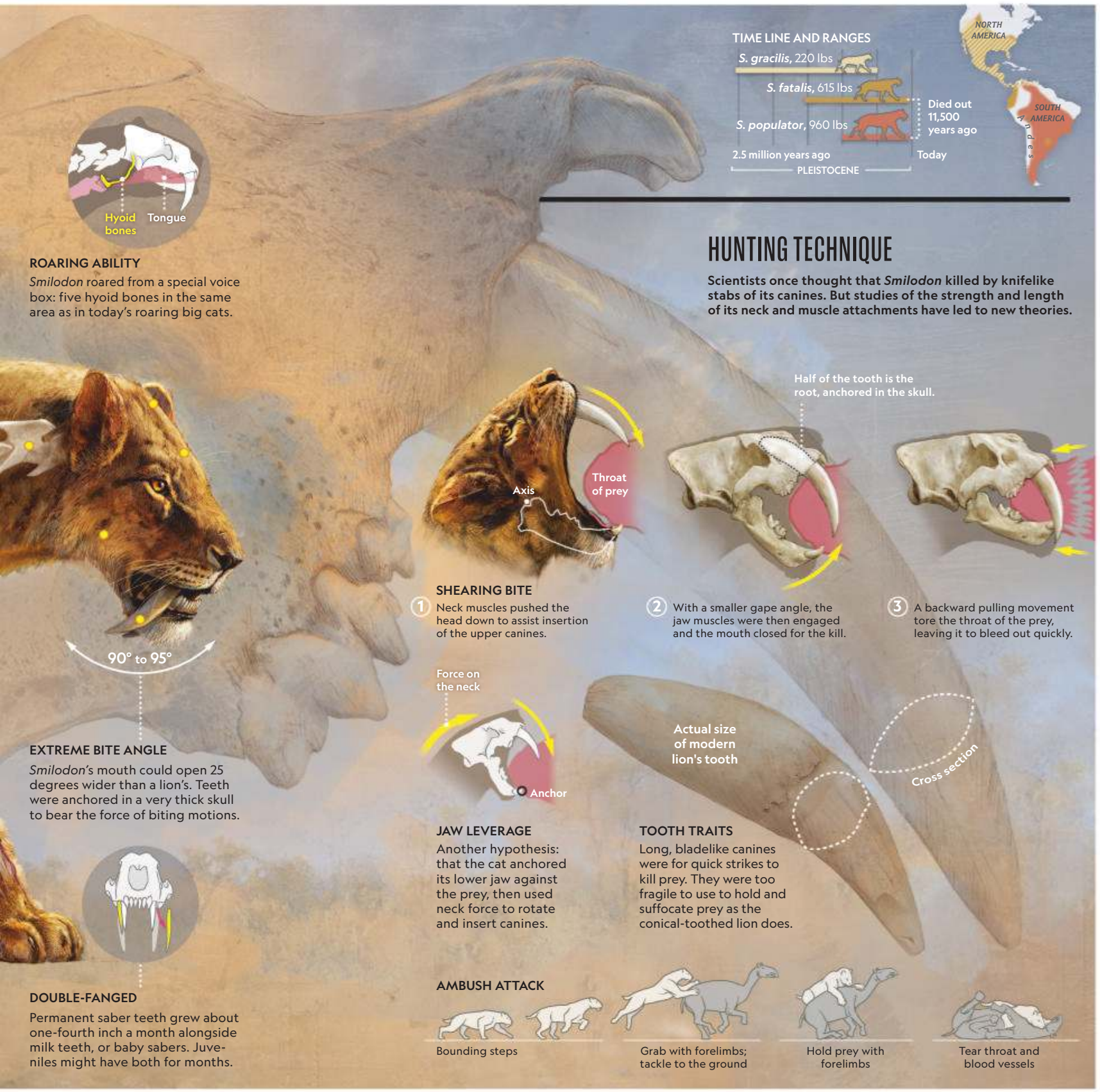
POWERFUL FORELIMBS

Unlike other cats' bones, these were reinforced—dense outer layer, thick interior—so prey could be subdued quickly with less risk to fragile canines.

MARKS OF INJURIES

Fossil signs—of broken bones and teeth, spinal and chest injuries, a puncture wound to the skull—speak to the life these cats lived.

MAURICIO ANTÓN, MUSEO NACIONAL DE CIENCIAS NATURALES, MADRID; HERVÉ BOCHERENS, U. OF TÜBINGEN AND SENCKENBERG CENTRE FOR HUMAN EVOLUTION AND PALAEOENVIRONMENT; NICOLAS R. CHIMENTO, MUSEO ARGENTINO DE CIENCIAS NATURALES; ALDO MANZUETT
URUGUAY; JULIE MEACHEN, DES MOINES U.; ASCANIO RINCÓN, VENEZUELAN INSTITUTE OF SCIENTIFIC RESEARCH; LA BREA TAR PITS; ADRIÁN PABLOS, CENTRO NACIONAL DE INVESTIGACIÓN SOBRE LA EVOLUCIÓN HUMANA, SPAIN. LION TOOTH CROSS SECTION: REDA MOHAMED, U. OF



ROARING ABILITY

Smilodon roared from a special voice box: five hyoid bones in the same area as in today's roaring big cats.

HUNTING TECHNIQUE

Scientists once thought that *Smilodon* killed by knifelike stabs of its canines. But studies of the strength and length of its neck and muscle attachments have led to new theories.

SHEARING BITE

1. Neck muscles pushed the head down to assist insertion of the upper canines.
2. With a smaller gape angle, the jaw muscles were then engaged and the mouth closed for the kill.
3. A backward pulling movement tore the throat of the prey, leaving it to bleed out quickly.

EXTREME BITE ANGLE

Smilodon's mouth could open 25 degrees wider than a lion's. Teeth were anchored in a very thick skull to bear the force of biting motions.

JAW LEVERAGE

Another hypothesis: that the cat anchored its lower jaw against the prey, then used neck force to rotate and insert canines.

TOOTH TRAITS

Long, bladelike canines were for quick strikes to kill prey. They were too fragile to use to hold and suffocate prey as the conical-toothed lion does.

DOUBLE-FANGED

Permanent saber teeth grew about one-fourth inch a month alongside milk teeth, or baby sabers. Juveniles might have both for months.

AMBUSH ATTACK

I, U. OF THE REPUBLIC,
F THE WEST INDIES

CROWNING GLORY

TRADITIONAL HEADDRESSES RULE AGAIN IN UKRAINE.

PHOTOGRAPH BY **DOMINIKA DYKA**

FLOWERS, feathers, hemp threads, shells, beads, even pieces of foil and wax. These are some of the items that artist Dominika Dyka weaves into her modern re-creations of the classic *vinok,* or wreath.

Worn for centuries by girls and young women in Slavic countries, the wreaths are thought to have pagan origins. They are customary accessories for weddings and Ivan Kupala festivities, when women place their wreath in a river to divine their romantic future. Will the water's flow seal their fate—or will a man jump in to save it?

The wreaths are gaining new visibility thanks to artists, musicians, and scenemakers. "You feel like a royal when you wear one," says musician Daga Gregorowicz. And so do audiences: "They may wear Wellingtons at festivals in England—but here the hipsters wear crowns."

Dyka's versions—made with collaborators at her Third Rooster workshop in Lviv, Ukraine—are based on archival images from museums and crowdsourced family photos. Her goal is to catapult traditional crafts into colorful emblems of national pride. "Earlier craftswomen had fewer materials to choose from," says Dyka, but "fantastical imaginations." **—EVE CONANT**

Musician Dana Vynnytska, of the Ukrainian-Polish band DAGADANA, wears a modern *vinok*. The wreath is festooned with dried plants, sticks, and paper flowers.

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THE STATE OF WOMEN

BY **IRENE BERMAN-VAPORIS, LAWSON PARKER,** AND **ROSEMARY WARDLEY**

Employment • Education • Maternal mortality • Political clout • Physical safety

How U.S. women fare in these key aspects of life varies widely across the nation, according to a new benchmark of women's well-being. The 2020 U.S. Women, Peace and Security Index measures women's inclusion in society, sense of security, and exposure to discrimination. It shows how obstacles and opportunities for women differ from state to state, driven by economic, racial, and ethnic disparities, among other factors.

National Geographic **partnered with the Georgetown Institute for Women, Peace and Security to illustrate the U.S. index.**

The index measures three categories, each composed of four subcategories.

Inclusion Justice Security

National average

43% Employment
Women age 16 and older who work 35 hours or more every week

33% Education
Women age 25 and older who have a bachelor's degree or higher

30% Government representation
Seats held by women in both chambers of the state legislature

6% Working poor
Poverty among women who worked 27 weeks or more in the past year

2.5 Legal protection
Number of key laws (out of seven) enacted to protect women's rights

28% Discriminatory norms
Men age 18 and older who say it's better if women work within the home

62% Reproductive health care
Women living in a county with a clinic that provides abortion services

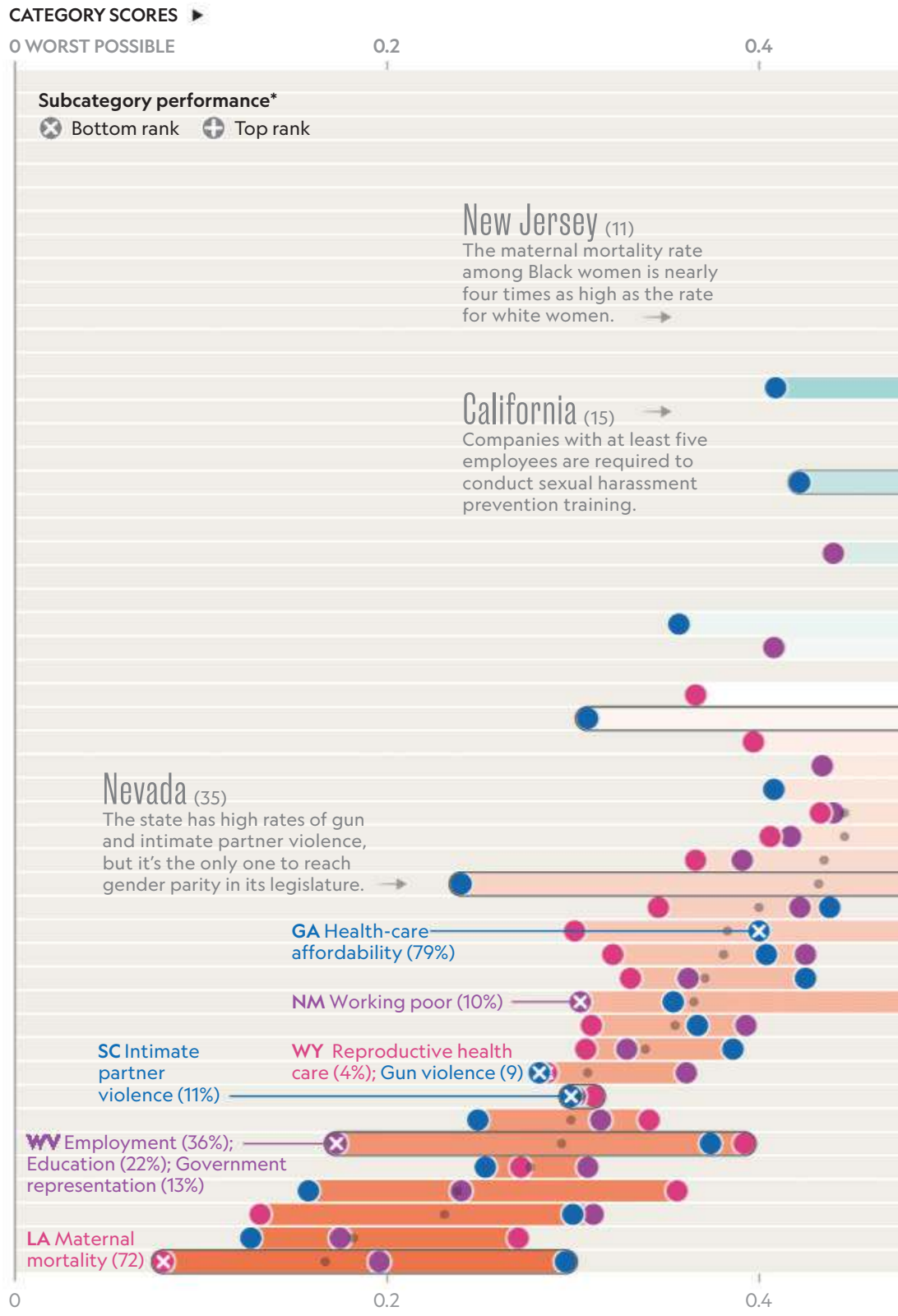
30 Maternal mortality
Deaths per 100,000 live births from any cause related to pregnancy

3 Gun violence
Deaths per 100,000 women from gun-related homicides or suicides in the past year

7% Intimate partner violence
Physically or sexually harmed or stalked in the past year by a partner

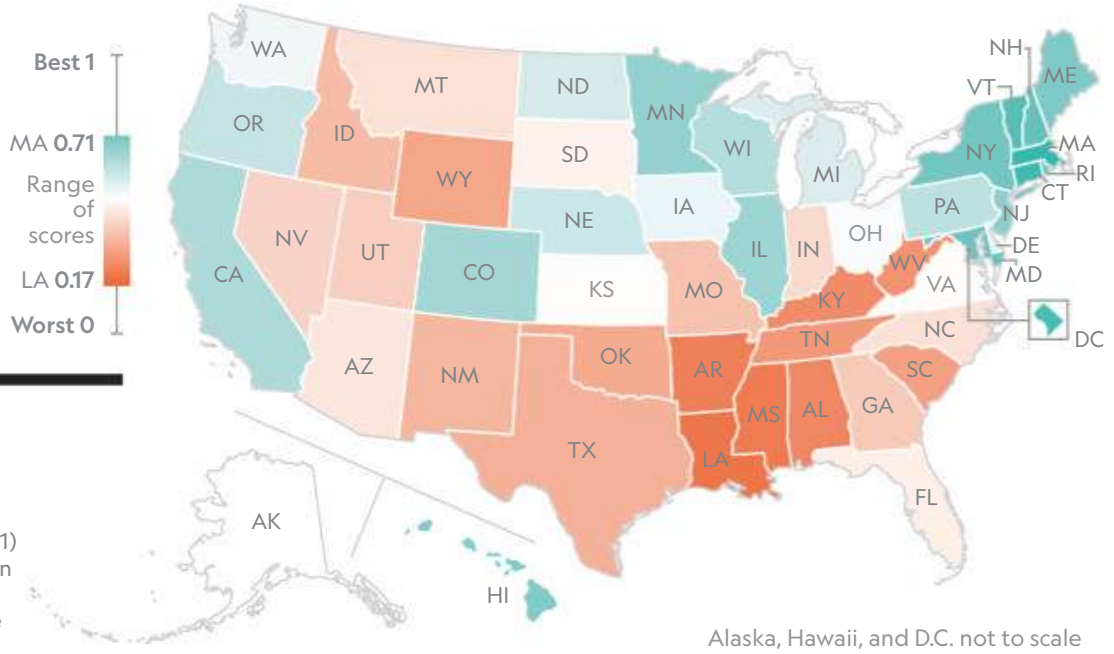
86% Health-care affordability
Women who visited a doctor in the past year without financial difficulty

56% Community safety
Women age 18 and older who aren't afraid to walk alone at night in their neighborhood



VISIT *USA-INDEX.COM* TO LEARN MORE ABOUT THE INDEX AND HOW IT WAS CREATED.

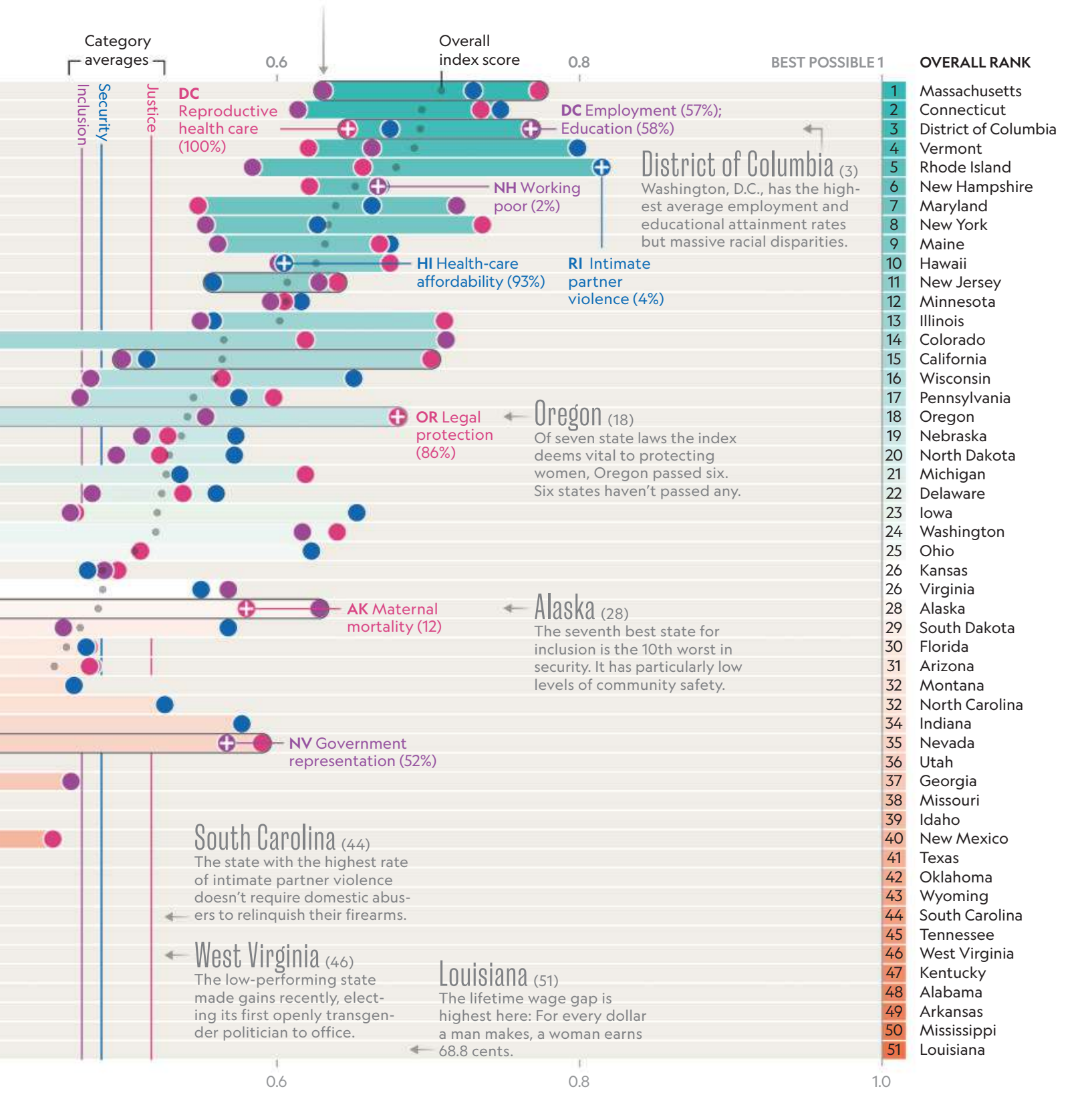
No place in the country achieves the best or worst possible score. All six New England states rank in the top 10; the five lowest performing states are located in the South.



Alaska, Hawaii, and D.C. not to scale

Massachusetts (RANK: 1)

Proactive legislative reforms in the state, including an equal pay act updated in 2018, have helped close gender gaps.



District of Columbia (3)

Washington, D.C., has the highest average employment and educational attainment rates but massive racial disparities.

Oregon (18)

Of seven state laws the index deems vital to protecting women, Oregon passed six. Six states haven't passed any.

Alaska (28)

The seventh best state for inclusion is the 10th worst in security. It has particularly low levels of community safety.

South Carolina (44)

The state with the highest rate of intimate partner violence doesn't require domestic abusers to relinquish their firearms.

West Virginia (46)

The low-performing state made gains recently, electing its first openly transgender politician to office.

Louisiana (51)

The lifetime wage gap is highest here: For every dollar a man makes, a woman earns 68.8 cents.

OVERALL RANK	
1	Massachusetts
2	Connecticut
3	District of Columbia
4	Vermont
5	Rhode Island
6	New Hampshire
7	Maryland
8	New York
9	Maine
10	Hawaii
11	New Jersey
12	Minnesota
13	Illinois
14	Colorado
15	California
16	Wisconsin
17	Pennsylvania
18	Oregon
19	Nebraska
20	North Dakota
21	Michigan
22	Delaware
23	Iowa
24	Washington
25	Ohio
26	Kansas
26	Virginia
28	Alaska
29	South Dakota
30	Florida
31	Arizona
32	Montana
32	North Carolina
34	Indiana
35	Nevada
36	Utah
37	Georgia
38	Missouri
39	Idaho
40	New Mexico
41	Texas
42	Oklahoma
43	Wyoming
44	South Carolina
45	Tennessee
46	West Virginia
47	Kentucky
48	Alabama
49	Arkansas
50	Mississippi
51	Louisiana

*SUBCATEGORIES WITH TIED SCORES NOT SHOWN ON GRAPHIC. THE INDEX RANKS ALL 50 STATES AND THE DISTRICT OF COLUMBIA. SOURCES: JENI KLUGMAN, ELENA ORTIZ, AND TURKAN MUKHTAROVA, GEORGETOWN INSTITUTE FOR WOMEN, PEACE AND SECURITY; INSTITUTE FOR WOMEN'S POLICY RESEARCH

CAPTURED

ENHANCED BY SCIENCE, COLORFULLY

Chemists and physicists are experimenting with ways to make shades inspired by nature even more vivid and intense.

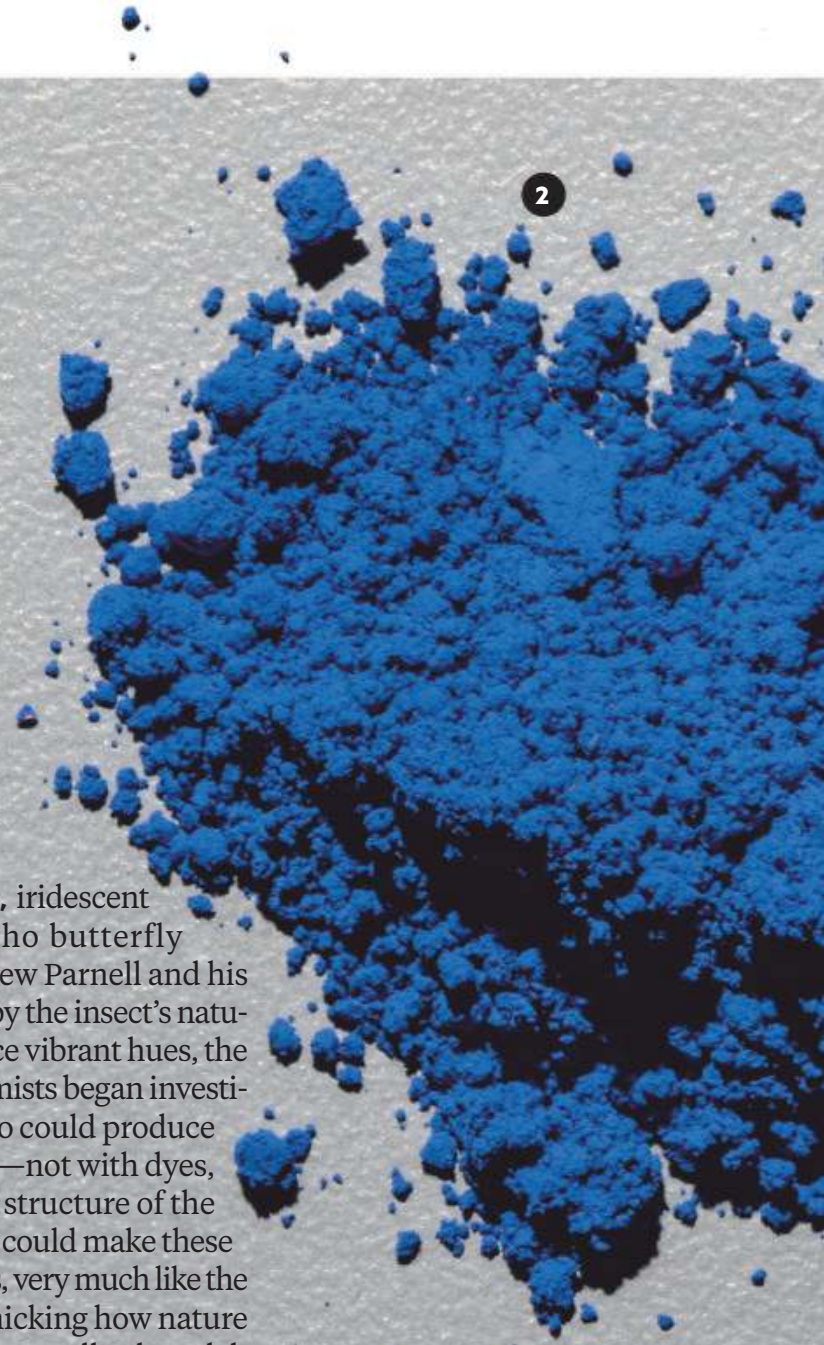
BY **SARAH GIBBENS**

IT WAS THE BRIGHT, iridescent blue of the morpho butterfly that inspired Andrew Parnell and his colleagues. Struck by the insect's natural ability to produce vibrant hues, the physicists and chemists began investigating how they too could produce eye-catching color—not with dyes, but by altering the structure of the material itself. "We could make these really nice reflectors, very much like the butterflies do, mimicking how nature makes them," says Parnell, whose lab at the University of Sheffield, England, studies colors that span the rainbow.

A pigment produces color by absorbing all but a specific wavelength of light. By contrast, colors produced by altering the arrangement of molecules reflect only a specific wavelength. Parnell calls it the science of controlling light.

Blue pigments occur rarely in nature. But some 4,800 miles to the west of Parnell's lab, at Oregon State University, materials scientist Mas Subramanian discovered a new blue pigment—by chance. Searching for a magnetic material that could store electricity and be used in computers, Subramanian and his graduate students stuck a mixture of the metallic elements yttrium, indium, and manganese into a furnace and were surprised to see that they'd created a bright blue substance. He named it YInMn, from the elements' symbols. ▯

1. Extreme black
The superblack pigment shown here, made by British artist Stuart Semple, is used in acrylic painting. Superblack coatings absorb nearly all visible light, almost like a black hole. They make three-dimensional objects look flat. The famous Vantablack has been used to coat a luxury vehicle and watches, but an even blacker black was made last year by MIT.



2. Extreme blue
Named YInMn (pronounced yin-min), it's the first new blue pigment discovered in the past 200 years. The vivid color is surprisingly effective at reflecting heat, making it useful in keeping buildings cool.

3. Extreme pink
The fluorescent pink pigment was created by Semple, who makes art materials and sells them online.

4. Extreme orange
Manufactured by the Shepherd Color Company, this RTZ Orange is also quite green—that is, free of toxic components such as lead and chromate.

5. Extreme yellow
Like RTZ Orange, NTP Yellow is made by Shepherd Color and is used to give coatings and plastics a vibrant, durable yellow color.

Hear more about the new blue pigment on a coming episode of our podcast, Overheard at National Geographic.

PHOTOS: REBECCA HALE, NGM STAFF


3
4
5
1

LUCKY CHARMS

9

Around the globe, artful objects offer hope and cultural connection.

BY **EVE CONANT**

1

PENCA DE BALANGANDAN

A customized collection
Worn by enslaved women during the 18th and 19th centuries in the Brazilian state of Bahia, the assortments of charms reflected the wearers' life experiences and wishes—such as prosperity, fertility, and freedom. Today gift shops and art galleries sell balangandans as jewelry and decorative objects.

MANEKI-NEKO

IN JAPAN THESE FELINE FIGURINES, OFTEN FOUND IN BUSINESSES, ARE THOUGHT TO BRING LUCK AND WEALTH TO THE OWNERS. WITH THEIR RAISED (AND SOMETIMES WAVING) PAWS, THEY WELCOME CUSTOMERS.

3

DALA HORSE

With origins in folk art—although one researcher posits a controversial connection to witchcraft—Sweden's wooden equines represent good fortune to some and are emblems of the country itself.

4

HAMSA

THIS PROTECTIVE SYMBOL, significant to both Jews (who call it hand of Miriam) and Muslims (hand of Fatima), shows up in necklaces, wall hangings, door knockers, and more, from Israel to Morocco.

5

NAZAR

IN TURKEY AND OTHER PARTS OF THE ISLAMIC WORLD, THIS OMNIPRESENT BLUE-AND-WHITE AMULET IS SUPPOSED TO AVERT THE CURSE OF THE EVIL EYE, A CONCEPT DATING BACK AT LEAST 5,000 YEARS.

PHOTOS (CLOCKWISE FROM TOP LEFT): A BEAUTIFUL TIME ANTIQUITIES; JON HELGASON, ALAMY STOCK PHOTO; TOBYPHOTOS, ALAMY STOCK PHOTO; NURPHOTO VIA GETTY IMAGES; PAUL STRAWSON, ALAMY STOCK PHOTO

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FEATURES

82

‘LULLABIES EXPRESS NOT JUST OUR GREATEST FEARS, BUT IN THE SAME BREATH, OUR HOPES AND PRAYERS. THEY ARE LIKELY TO BE THE FIRST LOVE SONGS CHILDREN HEAR.’

PHOTO: HANNAH REYES MORALES

SO GREAT,

SO FRAGILE

THE GREAT LAKES HOLD 84 PERCENT OF NORTH AMERICA'S SURFACE FRESHWATER. THEY HELPED MAKE THE UNITED STATES AN AGRICULTURAL AND INDUSTRIAL POWERHOUSE. BUT NOW **CLIMATE CHANGE, POLLUTION, AND INVASIVE SPECIES** THREATEN THE CONTINENT'S MOST VALUABLE RESOURCE.

BY **TIM FOLGER**

PHOTOGRAPHS BY **KEITH LADZINSKI**

LAKE ERIE

A massive algal bloom carpeted western Lake Erie in the summer of 2019. At its peak the bloom covered more than 600 square miles. The blooms can release toxins into the water that blister skin and damage the liver. Once rare, they now occur almost every summer.

PREVIOUS PHOTO

LAKE MICHIGAN

Floodwater pours over a walkway at Montrose Beach near downtown Chicago. In the first half of 2019, heavy rains raised the lake level by almost two feet. Scientists expect the frequency of extreme weather to increase across the region in the decades ahead.

LAKE MICHIGAN

Wheeling gulls compete for bread crumbs at Indiana Dunes National Park, which had more than two million visitors in 2019. Shaped by the retreat of glaciers, the shores of the Great Lakes have hosted humans for thousands of years.

LAKE SUPERIOR

The Hurricane River, on Michigan's Upper Peninsula, empties into the south shore of Lake Superior, the planet's largest body of freshwater measured by surface area. The lake, which holds more than half the total water of all five Great Lakes, faces a range of threats, from invasive species to the loss of winter ice.

For the Anishinaabe, hunting has never been a sport, and life is never taken lightly.

SO WHEN THE BIG BULL MOOSE approached Tom Morriseau Borg, he felt a mix of gratitude, awe, and humility: The moose was offering itself, a gift of life and meat from the forest that Borg would share with family and friends. Borg, a traditional Anishinaabe trapper, grew up near Lake Nipigon in western Ontario in a home without electricity or running water. The Anishinaabe have fished, hunted, and trapped there for centuries, and after Borg shot the moose, he sprinkled tobacco on the animal and whispered some prayers of thanks, just as his grandfather had taught him.

But as he dressed the carcass—cutting it up to bring home—Borg's gratitude gave way to revulsion. When he tried to extract the liver, which should have been firm and meaty, it deliquesced into a bloody sludge, sliding goopily through his fingers. Since that hunt, Borg has found similarly diseased livers in several animals. "I notice it in rabbits, beavers, and in partridges," he said. "The favorite part of the rabbit for me was the rib cage, with the heart and the

LAKE MICHIGAN

Steel production once boomed in Whiting and Gary, Indiana, and all along the southern edge of Lake Michigan. Since 2000, Gary has seen tens of thousands of residents leave as overseas competition and the U.S. shift away from heavy manufacturing gutted the area's economy.

PANORAMA COMPOSED OF SIX IMAGES

GREAT LAKES IN PERIL

One of the world's largest sources of surface freshwater is in trouble. Environmental stressors such as climate change, invasive species, toxic chemicals, agricultural pollutants, and coastal development are degrading the Great Lakes ecosystem. Lake Superior is the least threatened; Lakes Erie, Ontario, and Michigan are most at risk.

LAKE SUPERIOR

Waning ice, warming waters
With lightly populated shores, the lake experiences relatively low stress, but shrinking ice cover and higher water temperatures are a major concern for sensitive aquatic species and winter tourism.

581,000 people; 2.5 billion gallons used per day

LAKE MICHIGAN

Dangerously clear water
Its water is increasingly clear because invasive mussels filter phytoplankton; that doesn't mean the water is healthy. Without plankton, many species have suffered.

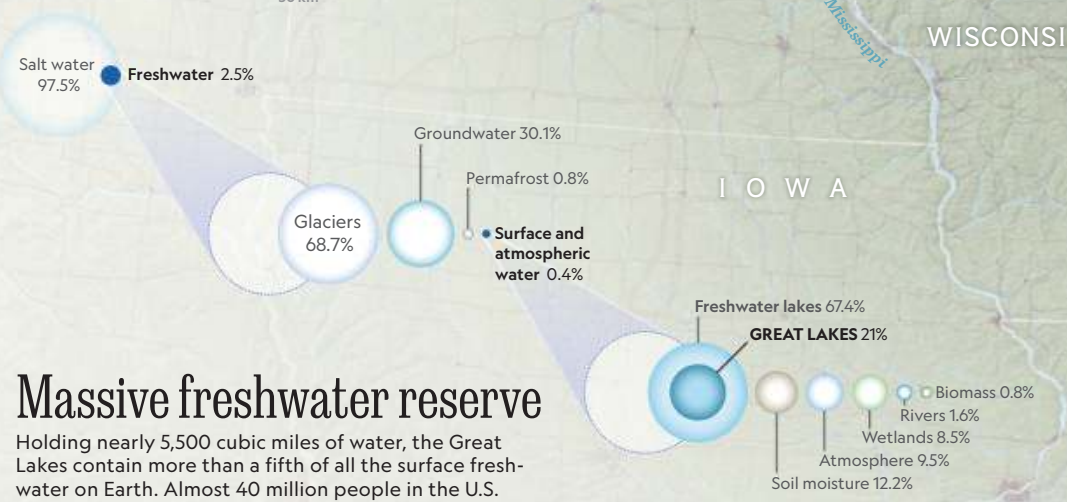
13.3 million people; 10.8 billion gallons used per day

Infrastructure
- Limited-access highway
- Main road
- Railroad
- Navigable canal

Stress on the lakes from human factors
Lowest — Highest

Great Lake basin boundary

50 mi
50 km



Massive freshwater reserve

Holding nearly 5,500 cubic miles of water, the Great Lakes contain more than a fifth of all the surface freshwater on Earth. Almost 40 million people in the U.S. and Canada rely on these five lakes for drinking water.

MATTHEW W. CHWASTYK, JASON TREAT, AND ROSEMARY WARDLEY, NGM STAFF; KELSEY NOWAKOWSKI
SOURCES: GREAT LAKES ENVIRONMENTAL ASSESSMENT AND MAPPING PROJECT; STATISTICS CANADA; U.S. CENSUS BUREAU; GREAT LAKES COMMISSION; U.S. EPA; NOAA; USGS; GREEN MARBLE; DAVID ALLAN AND OTHERS, *PNAS*, JANUARY 2013

ir future is isk from:

Pollution

Agricultural runoff from extensive fertilizer use and overflowing sewers creates an overabundance of nutrients in the lakes. This leads to toxic algal blooms that rob the waters of life-sustaining oxygen.

Warmer waters

As waters heat up, they stress the native flora and fauna that are adapted to the normal lake temperature cycle. Warming also reduces the number of days that the lakes are ice-covered.

Invasive species

Interlopers foreign to the lakes have upended the food web—to the detriment of native species. Many arrived in the ballast tanks of freighters; some were introduced for sportfishing.

LAKE HURON

Plummeting fish stock

Like its neighbor Superior, Huron has relatively undeveloped shores. Invasive mussels and a period of salmon overstocking led to longer-term declines in baitfish and salmon populations.

3.1 million people; 8.3 billion gallons used per day

Opening to the ocean

Canals were cut through natural barriers, connecting the lakes to the Mississippi River system and easing access to the Atlantic Ocean. But this also exposed the lakes to non-native species.

LAKE ERIE

Too many nutrients

As the shallowest of the five lakes, Erie has a substantial number of stressors, including a high coastal population density and elevated pollution levels. Agricultural runoff causes dangerous algal blooms.

12.2 million people; 6.9 billion gallons used per day

LAKE ONTARIO

Urban pollution threat

Development, pollution from stormwater and sewage, and electricity generation contribute to high stress levels. Power plants that use lake water for cooling kill many larval fish.

10.2 million people; 10.3 billion gallons used per day

Wawa
Sault Ste. Marie
Sault Ste. Marie
Greater Sudbury
Blind River
Lake Nipissing
North Channel
Manitoulin I.
LAKE HURON
Georgian Bay
Alpena
Midland
Collingwood
Barrie
Lake Simcoe
Nottawasaga Bay
Saginaw Bay
Bay City
Midland
Saginaw
Flint
Lansing
Port Huron
Sarnia
St. Clair
Thames
London
Detroit
Windsor
Lake St. Clair
Chatham
Long Point
Erie
Battle Creek
Jackson
Ann Arbor
Adrian
Toledo
Cleveland
Sandusky
Bowling Green
Findlay
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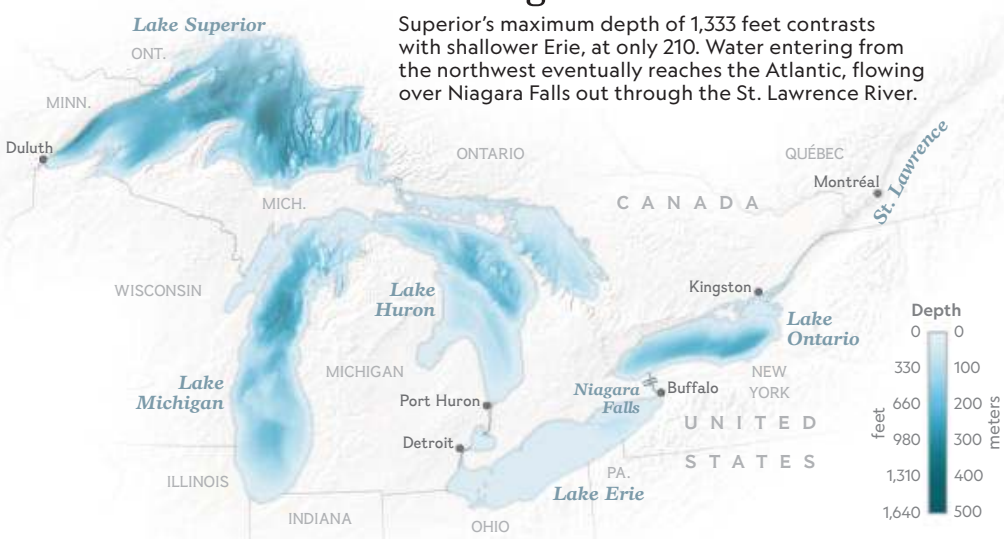
Syracuse
Cayuga–Seneca Canal
Finger Lakes
Albany
Hudson
St. Lawrence
Iroquois Canal
Wiley–Dondero Canal
Lake Champlain
To Gulf of St. Lawrence
800 miles
Québec
Montreal
South Shore Canal
Beauharnois Canal
Ottawa
CANADA
UNITED STATES
Montpelier
VERMONT
N.H.
Adirondack Mountains
Concord
NEW YORK
Champlain Canal
To New York City
134 miles
MASS.
Springfield
R.I.
Hartford
CONN.
Long I. Sound
Long Island
Newark
New York
PENNSYLVANIA
NEW JERSEY
Harrisburg
Philadelphia
ATLANTIC OCEAN
ONTARIO
QUÉBEC
MICHIGAN
OHIO

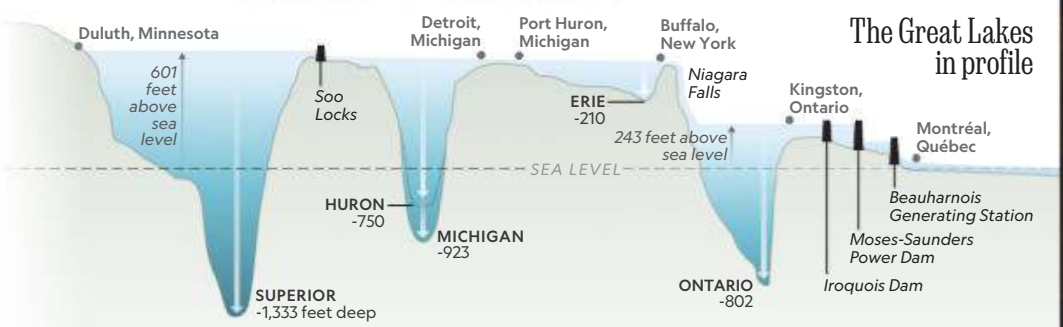
ICE-CARVED TREASURES

The Great Lakes formed when deeply grooved valleys—gouged by the advance and retreat of glaciers over thousands of years—filled with meltwater at the end of the last ice age.

From high basin to sea

Superior's maximum depth of 1,333 feet contrasts with shallower Erie, at only 210. Water entering from the northwest eventually reaches the Atlantic, flowing over Niagara Falls out through the St. Lawrence River.





LAKE MICHIGAN

As the sun sets, a curtain of rain descends from storm clouds near Sleeping Bear Dunes National Lakeshore on the northeastern coast of Lake Michigan. Of the five Great Lakes, only Lake Michigan lies entirely within the United States.

‘IT’S BIG, WHAT’S HAPPENING HERE … YOU KNOW SOMETHING IS WRONG.

liver. But now we don’t eat that anymore.”

Borg suspects that the spraying of herbicides by timber companies is hurting the animals in Lake Nipigon’s watershed. “New shoots are the moose’s favorite food,” he said. “They thrive on that new growth.” Or they did until it was poisoned. “That’s the way it works. Herbicides flow into streams to beaver lodges—that’s why their innards are so messed up.

“When I see harm and disruption, it hurts a lot. And the changes I’ve seen in the bush over the last 15 years—I didn’t think changes could come that fast,” Borg said as he finished the story on a cool summer evening at his home in Nipigon.

Borg has graying black hair and is trimly built, fit from a lifetime of hard work maintaining gas pipelines while trapping on the side. In the distance an occasional truck rumbled along the Trans-Canada Highway. From somewhere out in the night came the hauntingly wild cry of a loon.

Borg’s home, which he built with his wife and two sons among tall conifers 33 years ago, overlooks the Nipigon River, an outflow from the lake of the same name. Lake Nipigon covers nearly 1,900 square miles, but on a map it looks pondlike compared with the body of water it drains into: Lake Superior, the largest of the five Great Lakes, or as the Anishinaabe call it, Anishinaabewi-gichigami—the Anishinaabe’s Great Lake. (In Longfellow’s *Song of Hiawatha,* it’s Gitche Gumee, “the shining Big-Sea-Water.”)

As Borg’s wife, Donna, served us thick slices of bannock with rose hip jam, he lamented the transformation of a land he loves. Even the seasons have changed. Sometimes the lakes still have open water in December; winds are more violent; the winter coats of the animals he traps—beavers, marten, mink, weasels—develop later in the season than they did when he was a boy. “It’s not the same anymore.”

The sorts of changes Borg has seen—and many that he has not yet witnessed in his relatively pristine watershed—are transforming the rest of the Great Lake watersheds. The five lakes—Superior, Huron, Michigan, Erie, and Ontario—are arguably the continent’s most precious resource, incalculably more valuable than oil, gas, or coal. Together they hold more than a fifth of the world’s surface freshwater—six quadrillion gallons—and 84 percent of North America’s.

Almost 40 million Americans and Canadians live in the Great Lakes watershed. We drink from the lakes, fish on them, transport goods over them, farm their shores, and work in cities that wouldn’t exist without the lakes. And of course, we pollute them. We’ve introduced invasive species that have permanently altered the lakes. The fertilizers we use to grow the corn we feed to the animals we eat and to make the biofuels we pump into our vehicles have contributed to the resurgence of algal blooms so large they can be seen from space. And with our ongoing emission of greenhouse gases, we’ve even managed to reengineer the weather over vast stretches of the Great Lakes watershed, increasing the frequency of severe storms.

“It’s big, what’s happening here,” Borg said over tea. “When you spend time on the land, you know something is wrong. Things are changing. I don’t know if we can stop it.”

AS GIGANTIC GEOGRAPHICAL features go, the Great Lakes are newcomers on the continent. They’re a legacy of North America’s last ice age, when miles-thick glaciers stretched from southern Kansas to the Arctic. When the glaciers retreated 11,000 years ago, they gouged the basins that became the Great Lakes. It was only about 3,000 years ago, though, that the lakes’ current contours and drainage systems evolved, which makes them significantly younger than the oldest Egyptian pyramids. Nothing on Earth rivals the lakes—they’re the world’s largest freshwater system, a gift from one age on the cusp of momentous change to another. They’re connected; one flows into the next.

All the lakes, whether they’re cold and deep with wooded shores, like Lake Superior, or warm and shallow and ringed by industrial cities, like

Lake Erie, share a secret life. They're hosts to a hidden world that most of us will never see. You might, if you're lucky, glimpse a wolf on Isle Royale in Lake Superior; or catch a moose at dusk near the shore of Lake Huron; or maybe you'll reel in a 200-pound sturgeon in Lake Erie. But those marquee creatures overshadow a much humbler supporting cast, without which the lakes would die.

"Take a deep breath, and then take a second deep breath. One of those two breaths was made by diatoms," said Andrew Bramburger, a lake ecologist now with Environment and Climate Change Canada, the agency that administers and enforces much of the country's environmental policies. Last year he was still at the University of Minnesota Duluth, and on a rainy September afternoon in an empty classroom, he was extolling the life-sustaining role played by diatoms, a type of algae with rigid cell walls made of silica.

"Everyone calls the Amazon rainforest the lungs of the world," he said. "But it's actually the diatoms in the oceans, rivers, and lakes of the world that make about half the oxygen in our atmosphere." Diatoms pump oxygen into the lakes as well—without them, the lakes would suffocate. And they're the lakes' primary food source. If the diatoms are healthy, everything else in the lakes will be too.

Bramburger, who is sandy-haired and bearded, has spent 20 years studying algae in the Great Lakes and other large lakes around the world. He grew up near Niagara Falls and could be classified as an aquatic mammal himself. "I love to be in water," he said. "I learned to surf on Lake Erie. When you tell people you surf on a lake, they look at you kind of strangely." Then again, in most parts of the world, a lake is something you can see across. Bramburger's enthusiasm for the lakes was such that he couldn't help but share it, and not just verbally. He invited me to a special monthly event: a swim in Lake Superior with some friends. They do it year-round, even in the winter, when they'll jump from ice floes into open patches of water, he told me, cheerfully. And, lucky me, the next frigid baptism would be before dawn in four days. In a craven attempt to opt out, I mumbled that I hadn't packed a bathing suit. Bramburger cut me off: "You can borrow one of mine."

While I silently fretted about what I had gotten myself into, Bramburger opened his laptop to show me images of some of Lake Superior's smallest inhabitants. Researchers have identified about 3,000 species of diatoms in the Great Lakes, and there are probably many more to be discovered. Seen under a microscope, they're among the most strangely beautiful of all living things, with a kaleidoscopic variety of shapes—rococo orbs, striated lozenges, splayed fans, disks patterned like the rose windows in a Gothic cathedral. Like plants, diatoms and other algae use light to convert water and carbon dioxide into simple carbohydrates. They're high-quality food for zooplankton—minute, floating grazers—"juicy and rich in fats," in Bramburger's description.

Bramburger and other researchers have charted an alarming trend stretching back 115 years: Individual diatoms in the Great Lakes are getting smaller. The shrinkage seems to be connected with climate change. As the lakes warm, the diatoms sink, which reduces their ability to harvest light. "The bigger ones can't stay afloat," Bramburger said. "The trend is smaller diatoms and less of them, and they're being replaced by things that are at best low-quality food items and at worst toxic. We don't know what that's going to do to the overall food web."

Invasive species of mussels, introduced by oceangoing vessels, present an even greater threat to diatoms, causing their numbers in Lake Erie to plunge 90 percent in the past 35 years. The equivalent loss of other keystone plants with higher profiles—the grasses of the African savanna, say—would make global headlines. But diatoms don't get much press.

For such an abundant and irreplaceable organism, surprisingly little is known about

THINGS ARE CHANGING.
I DON'T KNOW IF WE CAN STOP IT.'

—TOM MORRISEAU BORG, TRADITIONAL TRAPPER

FARMING'S IMPACT

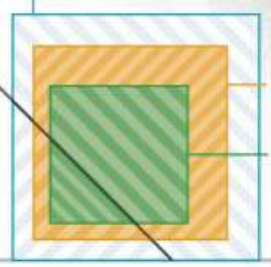
Freshwater is vital to the Great Lakes Basin agricultural industry, which pumps some 400 million gallons of basin water every day for irrigation. The region supports 25 percent of Canada's agricultural production and 7 percent of the United States', but water quality, wildlife habitat, and fish stocks have decreased in recent decades as a result of high fertilizer use and other pressures.

Total cropland
UNITED STATES
396.4 million acres

CANADA
93.4 million acres

Total cropland in the Great Lakes basins
28.2 million acres

Intensive monocropping...
Growing one crop on the same land each year is common. Row crops such as corn, soybeans, and hay dominate the southern Great Lakes region.



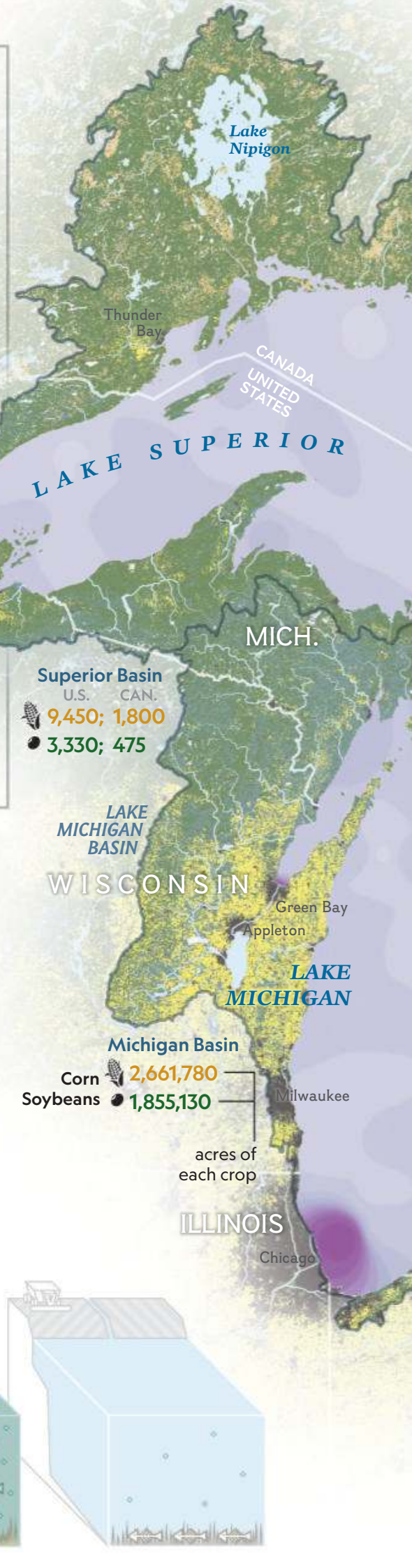
Total cropland for corn
8.6 million acres

Total cropland for soybeans
8.8 million acres

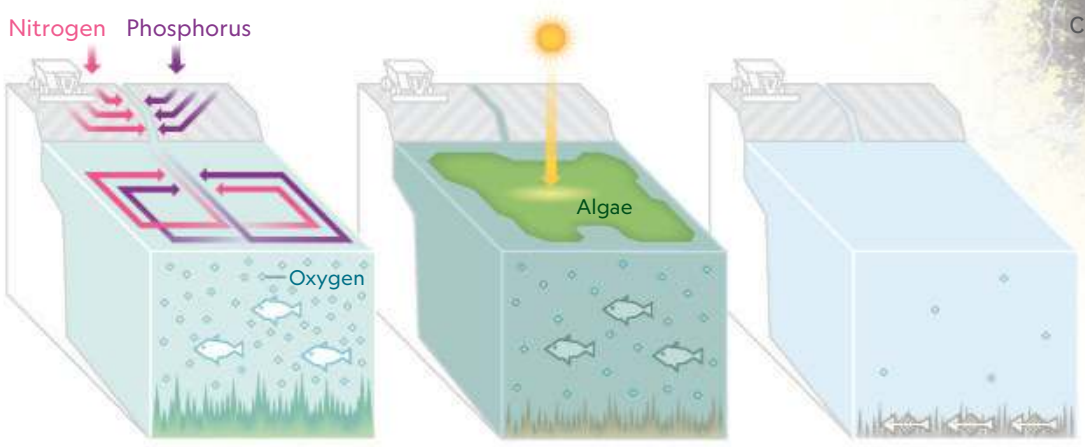
Total cropland treated with commercial fertilizer, lime, and soil conditioners
19.7 million acres

Total cropland treated with manure
4.4 million acres

...requires a lot of fertilizer...
The longer a piece of land is used for a single crop, the more fertilizers are needed to replenish soil nutrients that can't regenerate naturally.



...which leads to massive algal blooms.
Fertilizer nutrients such as nitrogen and phosphorus drain into the tributaries that feed the lakes, causing a range of adverse impacts.



Fertilizer and manure, rich in nitrogen and phosphorus that are not taken up by crops, enter tributaries and eventually the lakes.

Algae feast on the excess nutrients, resulting in massive blooms that absorb sunlight and oxygen, suffocating plants and animals.

The dead plants and algae decompose; bacteria further rob the system of oxygen as they break down the organic material.

MATTHEW W. CHWASTYK AND JASON TREAT, NGM STAFF; KELSEY NOWAKOWSKI
SOURCES: U.S. DEPARTMENT OF AGRICULTURE; AGRICULTURE AND AGRI-FOOD CANADA; NASA; USGS; U.S. EPA; NOAA; USGS UPPER MIDWEST WATER SCIENCE CENTER

Land cover
- Cropland
- Grassland
- Scrubland
- Forest
- Wetland
- Urban area

Total phosphorus concentration
High
Low

50 mi
50 km

Lake Superior

Lake Huron

Lake Ontario

Lake Michigan

Lake Erie

Phosphorus load
Each square represents 50 metric tons per year
- Upstream lakes
- Atmosphere
- Forest, wetland, and scrubland
- Farm fertilizer
- Other agriculture
- Manure
- Urban runoff
- Wastewater treatment plant discharge

Huron Basin

	U.S.	CAN.
	728,060;	643,710
	789,310;	681,730

LAKE HURON BASIN

ONTARIO

Sault Ste. Marie

Greater Sudbury

LAKE HURON

CANADA
UNITED STATES

St. Lawrence

LAKE ONTARIO

Toronto

Rochester

Syracuse

Hamilton

Buffalo

NEW YORK

MICHIGAN

Grand Rapids

Flint

Lansing

Lake St. Clair

Detroit

Windsor

LAKE ERIE

Erie

LAKE ONTARIO BASIN

Erie Basin

	U.S.	CAN.
	1,981,200;	1,139,150
	2,800,020;	1,227,960

Ontario Basin

	U.S.	CAN.
	552,040;	282,500
	232,590;	374,420

PA.

Toledo

Cleveland

INDIANA

Fort Wayne

Historic Great Black Swamp

OHIO

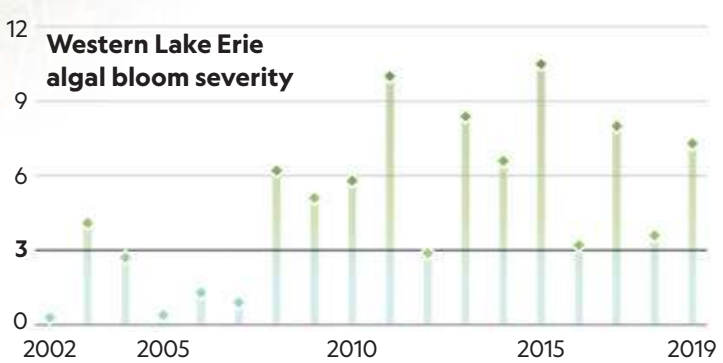
LAKE ERIE BASIN

A glut of nutrients

Natural processes, fertilizer runoff, and sewage-treatment wastewater supply an over-abundance of phosphorus and nitrogen to the lakes, leading to toxic algal blooms.

Algal blooms

Lake Erie's algal blooms have worsened over the past decade. Viewable from space, the blue-green, nutrient-loaded water persists for weeks, threatening human health, drinking water, and wildlife.



Algal bloom severity above 3 is harmful for water quality.

Great Black Swamp

This 1,500-square-mile marsh once served as a natural sink for excess nutrients. It was mostly drained by 1900 so that settlers could farm its fertile soils.

LAKE HURON

A 32-row planter spreads bean seeds on a portion of Zwerk and Sons' 7,500-acre farm in Vassar, Michigan, near Lake Huron. More than 5,000 farms in Michigan have been certified through a voluntary program boosted by state and local agencies to promote practices that reduce pollution.

DULUTH, MINNESOTA, THE SECOND LARGEST CITY ON LAKE SUPERIOR,

what happens to diatoms in the winter. "Five months of the year the lake is covered with ice," Bramburger said, "and we haven't got the foggiest idea of what's going on down there."

During the winters of 2017 and 2018, Bramburger and a few colleagues at the University of Minnesota set out to remedy that gap in our knowledge and ventured onto the frozen surfaces of several lakes that drain into Superior to drill some holes in the ice. "We just had our minds blown," Bramburger said. Instead of the sluggish scene they expected, the waters beneath the ice brimmed with life. "The photosynthetic rates happening under the ice were 60 percent of what they are in the summer. And that was under two feet of ice and two feet of snow. So you think it's just a cold, dark, boring world down there, but there's actually a lot going on." Zooplankton abounded—about 1,500 of them per liter—all swimming about, gobbling up algae.

Without a healthy crop of diatoms to support the zooplankton's winter feeding frenzy, the lake's productivity for the rest of the year would suffer. Because small fish in the lakes eat zooplankton, a plunge in the diatom numbers would cause fish populations to crash. "It's the jump start of the spring food web," Bramburger said. The solar energy snagged by diatoms provides the calories that become the flesh of ever larger creatures in a daisy chain of embodied light. "If you're catching big bass in the summer," Bramburger said, "it's because these guys were doing their thing in the winter."

One of the group's most counterintuitive discoveries was that diatoms were more efficient beneath snow-covered ice than beneath ice that had been cleared of snow. Diatoms need just the right balance of depth and sunlight. If they sink too deep, they don't get enough light. If they're higher up in the water column, they can get burned. Snow may be protecting them from excessive sunlight. Under cleared ice, solar radiation may damage the diatoms' photosynthetic pigments. One explanation: "Their photo systems, their pigments, were basically getting nuked and bleached," Bramburger said.

It was a worrisome find. "This is something that's going to affect the Great Lakes as we lose our snow and ice cover and as our winters get warmer but also drier and windier," Bramburger said. "Drier and windier means we're going to start losing snow on the ice, and as it gets warmer, we're just going to start losing ice. In the Great Lakes we see large algal blooms of a species called *Aulacoseira*. It's a big diatom, and it likes to be on the bottom of thick, snow-covered ice. If we start losing that, we'll probably lose one of the really important components of the food web.

"The thing I'm always struck by is that we don't understand winter, but we're losing it. It's a race to figure out what happens in winter before there's no winter to figure out."

Heavy rain was forecast for the morning of our swim, which had given me hope that I might yet avoid the ordeal. No such luck. At 5:30 a.m. on the appointed day, 13 of us huddled around a bonfire on a dark, fogbound, rocky beach not far from downtown Duluth, drinking coffee. This group plunge would mark 47 consecutive months of, well, jumping into a lake. Michael Scharenbroich, one of Bramburger's friends, took the water's temperature: "Fifty-one degrees," he yelled. Go time. Without water shoes, I lagged behind the collective charge, and hobbled over stones dropped by glaciers millennia ago. Then the need to relieve the pain in my feet overcame a visceral reluctance to dive in. All around me heads vanished and quickly reappeared above the surface, like a pod of startled otters, wide-eyed with shock and glee.

One jump, it turned out, wasn't enough. We warmed up and went in again. And a third time. As the bonfire dwindled and the sky lightened to a silvery gray, people started to leave, but Bramburger lingered. In a few days he would be moving to Canada to start a new job, and it was clear he would miss mornings like this. "I've lived around many places in the Great Lakes, but Lake Superior seems to have a bit of magic for people," he'd told me. "The sense of identity and attachment to the lake that Dulut never seen on another town on the la

For all its beauty, Lake Superior car erous. Duluth, with 86,000 people, ond largest city on Superior, after Th Ontario, and is still recovering from t done by a string of punishing storms one so-called 500-year storm, that b city within the past eight years. A few met with Bramburger, Michael LeBea no-nonsense construction project s gave me a tour of the waterfront, wher levels and three intense windstorms l extensive flooding damage the year b

In 2016 one storm knocked out the Duluth's water supply. A city on the e of the world's largest bodies of freshw within hours of running out of wate out over a stretch of prime urban sho soon will be protected by 76,000 ton mined from a nearby quarry, LeBea what the future would bring. "I'm almost exhausted the quarry," he sa going to be spending close to $30 m three big storms. For a small and wealthy city, it has been a big blow. W

building now is the best we can afford conceivable that if these storms cont worse, it won't be possible to get bac we were. And no one can understand

Such city-pounding storms are likely a costly new normal. Global warming lizing the jet stream, the high-altitude that flows from west to east around The temperature differences betwe and high latitudes that drive the jet st declined, slowing that vast river of ai has affected seasonal weather patter are becoming simultaneously mor and more intense. Some climate mod that the number of extreme rainstor wide will double with each one-degr increase in global warming, a trend th may be under way. Heavy spring ra led to record-high lake levels and w

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flooding across the Great Lakes region.

As we drove along the shoreline on the northern outskirts of the city, LeBeau said that a winter storm early in 2019 had covered the road we were on with four feet of sand and gravel. "We're looking at another three years of construction—assuming we don't get another big storm."

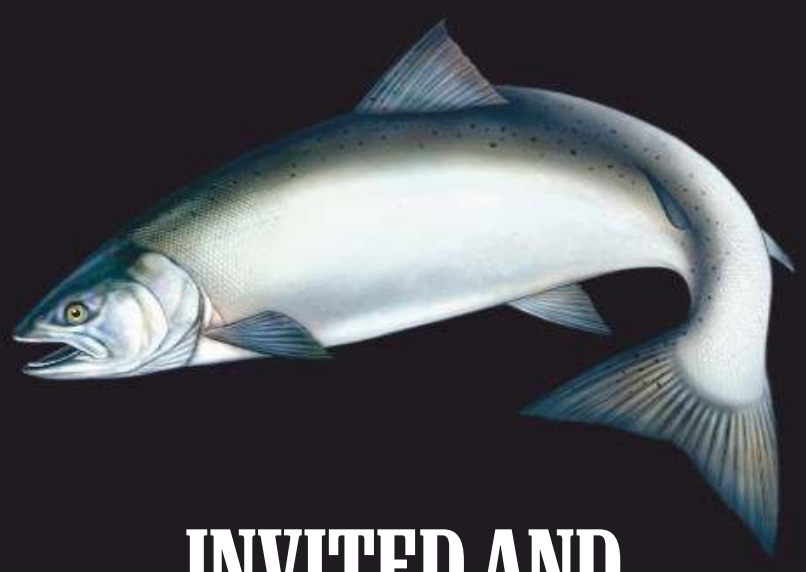
FIVE HUNDRED FIFTY MILES to the southeast, on another summer day pregnant with rain, a small group of women clustered around a red, diamond-shaped sign on a beach in Maumee Bay State Park, on the shore of Lake Erie a short drive from Toledo, Ohio. What they read troubled them: "DANGER Avoid all contact with the water. Algal toxins at UNSAFE levels have been detected."

The women, students from Bowling Green State University, had been swimming in the greenish water and had somehow missed seeing the sign before. We were the only ones on the beach, and when I approached, they asked questions I couldn't answer: Would they be OK? How dangerous were the toxins? "We'll never come back to this beach," said Marharita-Sophia Tavpash, visibly shaken, as she and her friends hurried back to their car.

Since the early 2000s, harmful algal blooms have plagued Lake Erie almost every summer. The Great Lakes host a variety of algae and similar organisms, and most of them, like diatoms, are essential for the lakes' health. But some can choke the life out of lakes. Most problematic are cyanobacteria, ancient organisms present in nearly every body of water. Given the right conditions—warm, polluted water—they grow explosively, forming slimy, green scum. When the algae decompose, they suck oxygen from the water, creating large dead zones, sometimes releasing toxins that can be fatal to wildlife. In humans they can blister the skin and damage the liver.

As recently as 25 years ago, algal blooms seemed to be a problem of the past. Before Congress passed the Clean Water Act in 1972, blooms had blighted the lake year after year. But the legislation imposed strict regulations on

AS BATTERED IN 2012 BY A
ALLED 500-YEAR STORM.



INVITED AND UNINVITED GUESTS

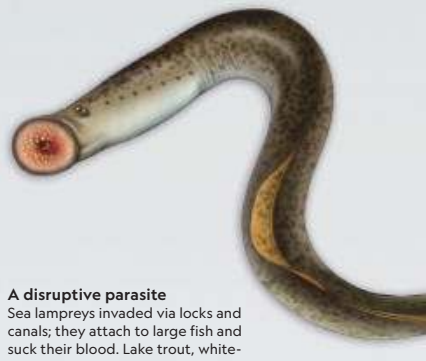
Not all non-native species in the Great Lakes are invasive. Some, such as the coho salmon, were purposefully brought in from Washington, Oregon, and Alaska in the 1960s to foster sportfishing and to stock the lakes after devastating declines in native lake trout populations. Fast-growing and predatory, the coho salmon thrive among other introduced fish, such as Chinook salmon and brown and rainbow trout. Whether introduced intentionally or not, non-native species have forever altered the food web of the lakes.

ILLUSTRATION: FIORELLA IKEUE

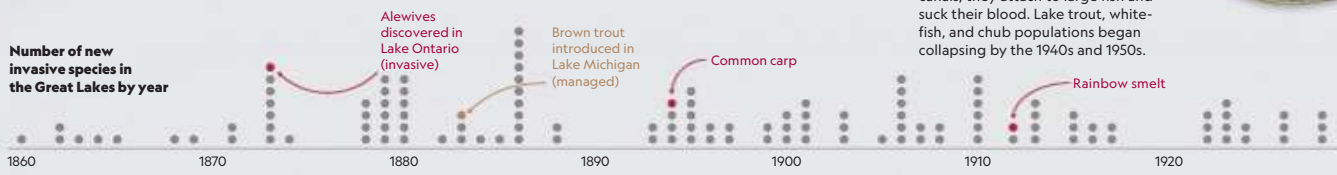
A FOOD WEB DISRUPTED

A thriving, complex food web is crucial to the health of one of Earth's largest surface freshwater ecosystems. But introductions and invasions of non-native aquatic plants and animals, the harvesting and stocking of top predator fish, and elevated nutrient and contaminant levels have snarled the Great Lakes food web, affecting fisheries, wildlife, and the health of the ecosystem.

The original alpha
Lake trout were once at the top of the Great Lakes food chain. Their numbers were decimated during the past century after the introduction of the non-native sea lamprey.

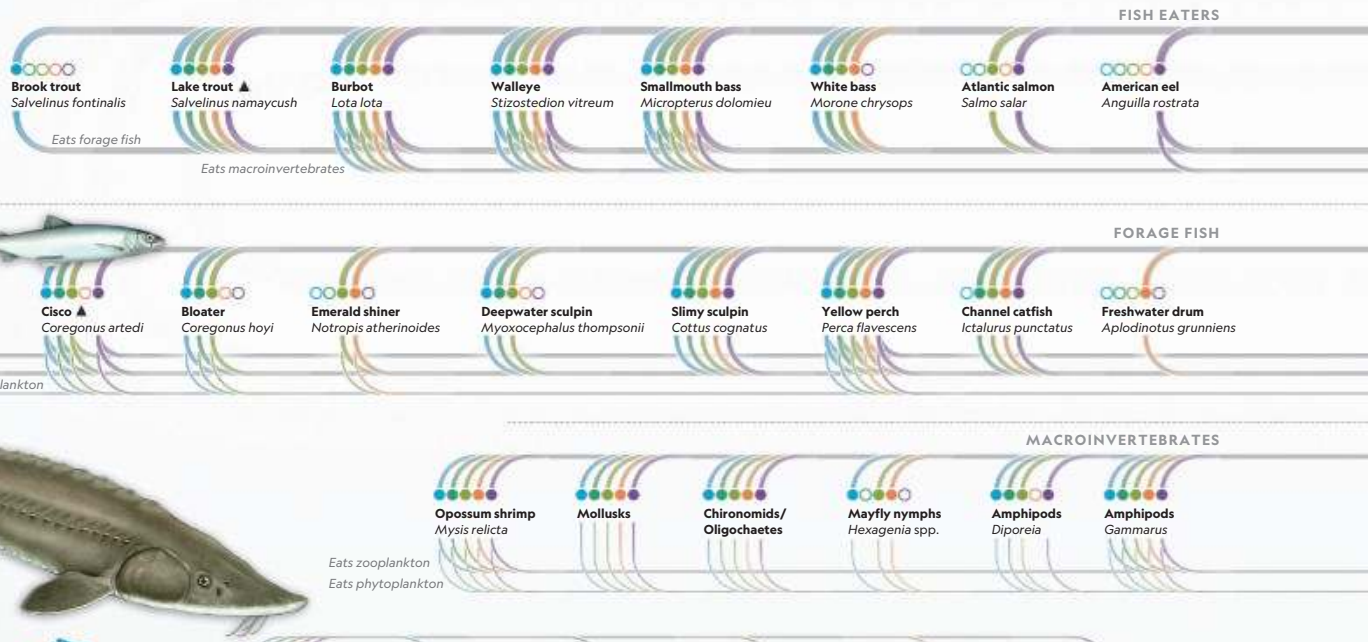


A disruptive parasite
Sea lampreys invaded via locks and canals; they attach to large fish and suck their blood. Lake trout, whitefish, and chub populations began collapsing by the 1940s and 1950s.



THE LAKES TODAY

More than 180 non-native species with reproducing populations continue to threaten the Great Lakes Basin.



Lake sturgeons are large, ancient fish that eat organisms on the lake bottom, including invasive mussels and round gobies.

CONNECTED BUT UNIQUE

The Great Lakes system includes the five Great Lakes (Superior, Huron, Michigan, Erie, and Ontario), Lake St. Clair, and their connecting channels. Each lake has distinctive basin features, circulation patterns, and ecologies.

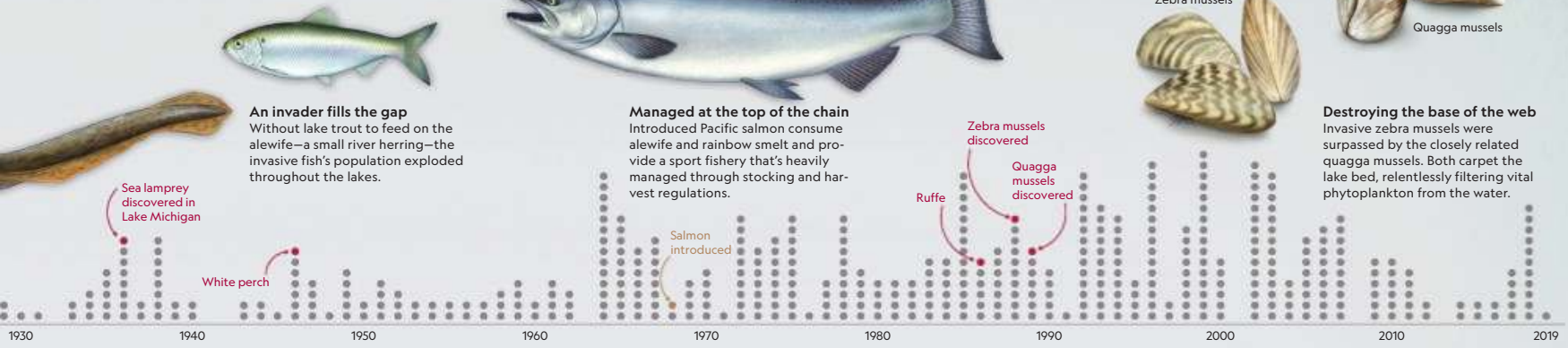
SUPERIOR
The coldest, deepest, and historically least productive of the Great Lakes, Superior now has 82 non-native species.

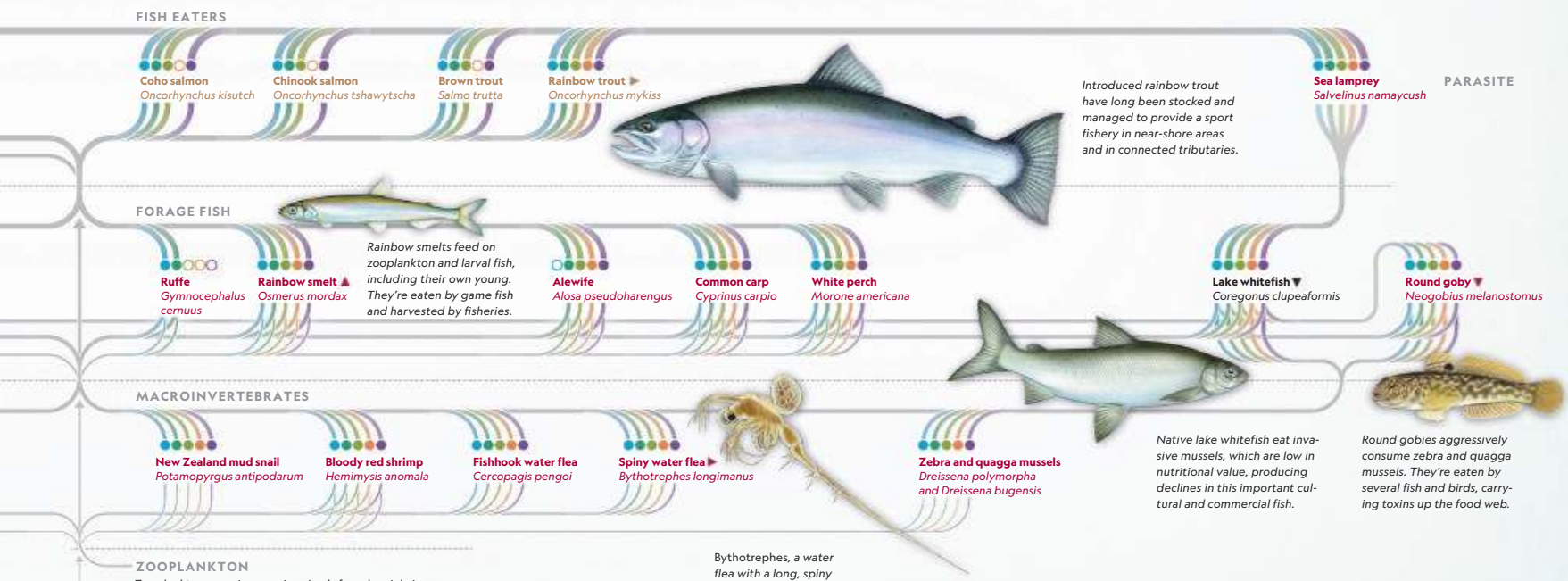
MICHIGAN
Lake Michigan stretches 307 miles north to south and is home to 94 non-native species.

HURON
With the longest shoreline of all the Great Lakes (3,830 miles, including islands), Huron now hosts 94 non-native species.

ERIE
Erie is the warmest, shallowest, and most productive of the Great Lakes; 148 non-native species are established there.

ONTARIO
Connected to the Atlantic Ocean via the St. Lawrence River, Lake Ontario has 104 non-native species.





A HIJACKED SYSTEM

Invasive species have rewired the Great Lakes food web. Sea lampreys attack top predators; round gobies compete with fish for food sources and habitat. Meanwhile, invasive mussels redirect the flow of energy, diverting food from the water column to the lake bed.

JASON TREAT, NGM STAFF; KELSEY NOWAKOWSKI
ILLUSTRATIONS: FIORELLA IKEUE
SOURCES: ASHLEY ELGIN, DORAN MASON, ED RUTHERFORD, AND ROCHELLE STURTEVANT, NOAA GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

LAKE HURON Top: The *William P. Rend*, a barge carrying limestone, sank in Lake Huron during a storm in September 1917. Now it's one of roughly 6,000 shipwrecks on the bottom of the Great Lakes. It's covered in part by zebra and quagga mussels, which were introduced by ocean vessels and now disrupt the lake's ecosystem. Above: Sea lampreys, an invasive species from the Atlantic, use their toothy, suction cup mouths to adhere to lake trout and other prey, gorging on blood and body fluids. A single lamprey can kill 40 pounds of fish in 12 to 18 months.

ILLINOIS RIVER

Illinois state fishermen catch Asian carp on the Illinois River, hoping to prevent their spread to Lake Michigan. Since escaping from aquaculture and sewage ponds in the Mississippi River Basin during the 1960s and 1970s, the carp have decimated native fish. They've recently been found nine miles from Lake Michigan.

DETROIT RIVER

The Detroit River divides Windsor, Ontario (left), from Detroit on its course to Lake Erie. In 1969 one of the Detroit's tributaries, the River Rouge, was so polluted it caught fire, an event that helped provoke the environmental movement in the U.S.

NEARLY EVERY SUMMER FOR THE PAST 20 YEARS, ALGAL BLOOMS

sewage treatment plants and led to the removal of phosphates from laundry detergents. Algae thrive on phosphorus; without large influxes of the element, the blooms can't grow. For one halcyon decade, the lake remained bloom free.

So why have the blooms returned? To meet the people who solved that mystery, I drove to Heidelberg University, in Tiffin, Ohio, whose 125-acre campus in the state's corn belt houses what some scientists call a national treasure: a meticulous, 45-year record of the chemicals that flow into Lake Erie from two large tributaries, the Maumee and Sandusky Rivers. The collectors and proud curators of that trove are two women who have devoted more than 40 years to the task of diagnosing Lake Erie's ills.

"We predate the EPA," said Ellen Ewing, over lunch at one of the university's dining halls. "We're older than Earth Day!"

Ewing, who has short gray hair and the crisp, assured manner of someone who knows her work inside and out, was talking about Heidelberg's National Center for Water Quality Research, founded in 1969. She has worked there since 1976, right after graduating from the university. Ewing started two years before her longtime colleague and fellow Heidelberg alum, Barbara Merryfield, sitting next to her at our table. Their job titles are lab manager and research associate, respectively—neither has a Ph.D.—but the data they've amassed over the decades have enabled researchers to understand the puzzling resurgence of Lake Erie's algal blooms.

Every week for more than 40 years, Ewing, Merryfield, and their small team have collected water samples from the Maumee, Sandusky, and other watersheds. "I used to drive 500 miles a week," Merryfield said. "I was out three days a week. Quite a few involved being stuck in the mud up to our axles." With her strong build and denim shirt, she still looked capable of dealing with a mired four-by-four.

"When Barb had a work anniversary, I calculated the number of samples she had processed," said Laura Johnson, an environmental scientist who has directed the center since 2016 and whose own work has been pivotal in unraveling the algal bloom conundrum. "It was way over two million, and I know that's an underestimate."

Every year they collect roughly 10,000 samples, testing each for 11 different parameters, Ewing noted, between bites of a salad. "We're wickedly efficient."

All that sampling revealed that a conservation practice that was supposed to improve the lake's water quality has had the opposite effect. In the 1990s many farmers in the lake's watershed incorporated "no-till" agriculture. Instead of plowing fertilizer into their fields every spring, farmers started to spread pellets onto the fields' surface. The reduction in plowing did reduce soil erosion, but it unexpectedly has increased the amount of algae food flowing into the lake. When phosphorus was plowed eight inches or so into the ground, it remained tightly bound to the soil. But with phosphorus pellets sitting in the upper inch or two of the soil, the phosphorus dissolves and washes into the lake whenever the soil becomes saturated with rainwater. Researchers now use spring rainfall data to forecast the severity of algal blooms.

The number of days with two inches of precipitation or more has more than doubled in the past two decades, Johnson said: "That's the big problem." But, she added, it's a problem we can fix. Johnson's mentor, Jennifer Tank, an ecologist at the University of Notre Dame, has been working with farmers on ways to reduce runoff from their fields—and to prepare them for the rigors of a new climate era.

The same heavy spring rains that washed phosphorus into Lake Erie forced farmers in the region to delay their spring planting in 2019. Fields were so wet and muddy that farmers fell weeks behind.

"A record number of acres weren't planted this year [2019]," said Kaleb Kolberg, a 26-year-old farmer in Hartford, Michigan, about 12 miles from the shore of Lake Michigan. Most people couldn't plant on one-quarter of their land. Pointing to

one of his own fields behind his home, he said, "That corn would normally be twice as high. We planted in conditions we never planted in before. We usually harvest corn in mid-September. This year it will be mid-October."

It had been a stressful year—on top of all the normal challenges of farming life. "It costs $600 to raise an acre of corn," said Kolberg, a muscular former college linebacker and self-described farm nerd. A single tractor costs $300,000. "You take all the risks up front and hope it pays off in the fall." Kolberg fared better than most. Working with Colleen Forestieri and Erin Fuller of the county conservation district and with Jennifer Tank, Kolberg had been planting cover crops of ryegrass and crimson clover for several years to protect his land during the off-seasons. Driving around southwestern Michigan with Kolberg in his pickup on a hot August afternoon, across a landscape planed by glaciers, even a lifelong urbanite could spot the farms that had planted cover crops. The corn grown on fields without them was noticeably shorter, sometimes by several inches; some fields weren't planted at all—they were just too wet for tractors. Some still held pools of standing water.

Kolberg said he was able to plant on more of his farm than his neighbors were able to plant thanks to cover crops, which pulled moisture out of the ground. "With cover crops, we're ready for the two extremes," he added, "too much water and too little."

Besides keeping farmers such as Kolberg in the black, the widespread use of cover crops would cut off the flow of nutrients that fuel algal blooms. "We need to protect every square inch of ground," Tank said. "That would be a game changer. We need watershed-scale cover crops."

For all their advantages, cover crops are a hard sell. "Cover crops require all the same care as regular crops," Tank said. Farmers don't make money on cover crops.

For now, fertilizer runoff from many farms remains unregulated under the Clean Water Act, even after a phosphorus-fueled bloom shut down the water supply of a major city.

On Friday, August 1, 2014, at about 7 p.m., Toledo's director of public utilities received a call from the department's chief chemist. Routine tests of the city's water showed that it had been contaminated with microcystin—an algal toxin. Advising residents to boil their water wasn't an option—it would only concentrate the poison. So at 2 a.m., the city issued a "do not drink" advisory. For more than two days, until the water was treated, nearly half a million Toledo residents couldn't drink from their taps.

Six years later, the catastrophe still rankles Wade Kapszukiewicz, Toledo's current mayor. "It caused businesses to close," he said. "It caused hospitals to not be able to do surgeries—if there's no water, there's no surgery. It was a traumatic event for our region."

His office, 22 floors above downtown Toledo, overlooks the Maumee River. Three years ago, he said, when a bloom on Lake Erie spread upriver, the Maumee looked as if it had been dyed green. The city has spent more than a billion dollars to upgrade its stormwater system and water-treatment plant, including improvements to filter and eliminate microcystin and a buoy with special sensors that monitor the extent of algal blooms near the city's water-intake pipe in Lake Erie. So a repeat of the crisis is unlikely—a reassuring bit of knowledge during a pandemic. Imagine a city without water now.

But Toledo, Kapszukiewicz said, is still paying a price for the unregulated release of phosphorus and other fertilizers into the lake. The problem is that not all farmers are as conscientious as Kolberg. "I don't need to be awake at 5:10 tomorrow morning to know that the sun will rise in the east," Kapszukiewicz said. "I also don't need to make yet another visit to yet another farm to know that agricultural runoff is polluting Lake Erie. Everyone already knows that. The only question is: What are we going to do to stop it?" he said. "I am not anti-farmer. I am antipollution. I know that many farmers are trying often very bold technologies to reduce agricultural

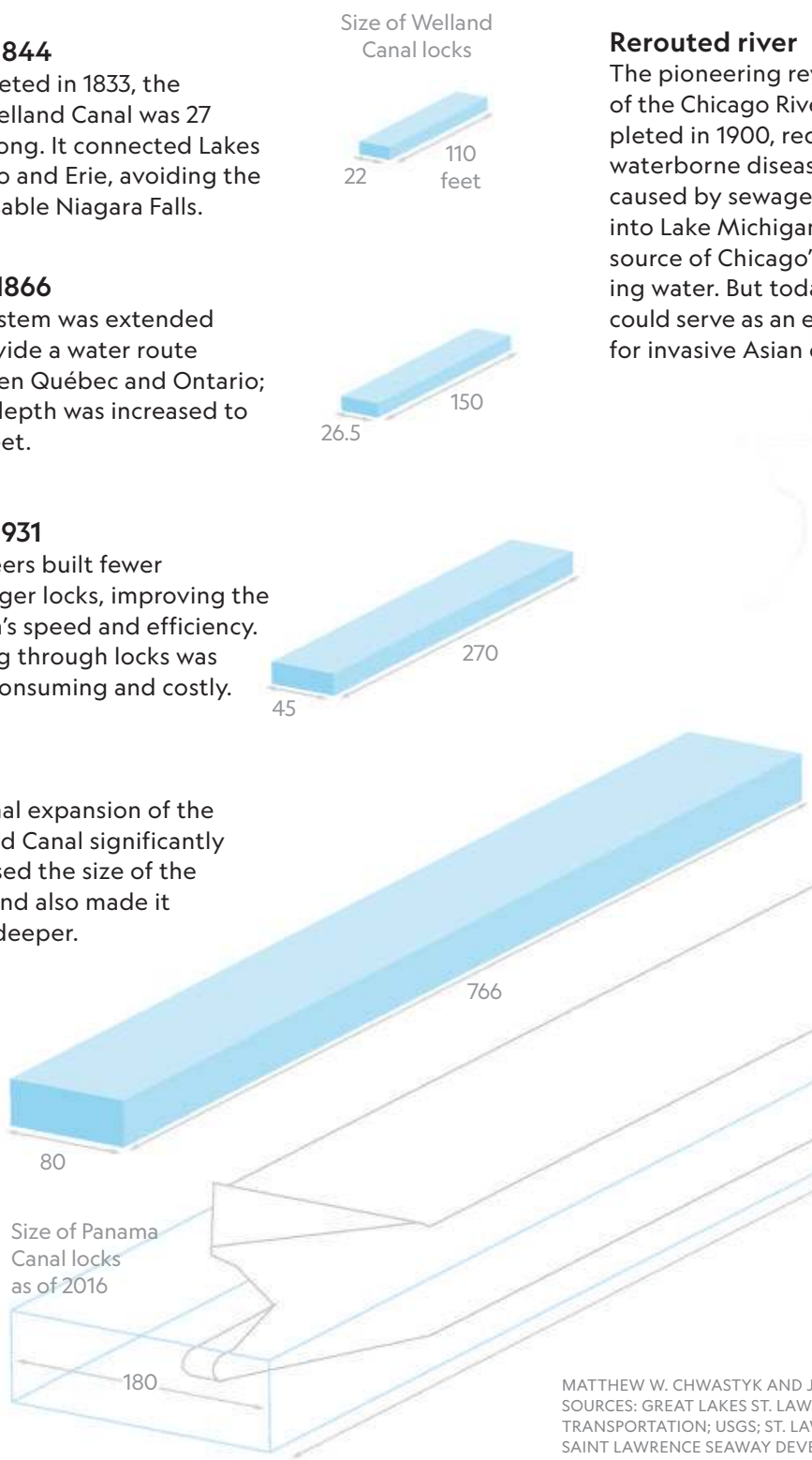
THAT CHOKE THE LIFE OUT OF LAKES
HAVE PLAGUED LAKE ERIE.

A THIRD COAST

The Great Lakes, with the longest coastline in the continental U.S., bustle with trade. Some 42 million tons of cargo moved through the St. Lawrence Seaway in 2019. The waterway has 15 locks and is part of a 2,340-mile route stretching from the Atlantic Ocean to Lake Superior. International shipping, a small share of the cargo trade, was once a leading pathway for invasive species.

LIMITED COMMERCE

Most foreign cargo ships, or "salties," are too large to pass through the relatively small seaway system locks; they can't sail inland past Montréal. To travel any farther, cargo must be loaded onto longer and narrower lake freighters, or "lakers."



1829-1844
Completed in 1833, the first Welland Canal was 27 miles long. It connected Lakes Ontario and Erie, avoiding the impassable Niagara Falls.

1845-1866
The system was extended to provide a water route between Québec and Ontario; canal depth was increased to nine feet.

1887-1931
Engineers built fewer but larger locks, improving the system's speed and efficiency. Moving through locks was time-consuming and costly.

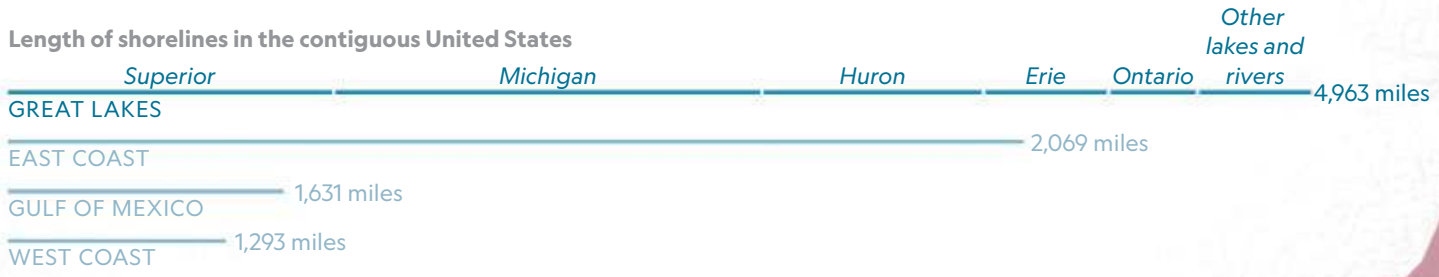
1932
The final expansion of the Welland Canal significantly increased the size of the locks and also made it much deeper.

Rerouted river
The pioneering reversal of the Chicago River, completed in 1900, reduced waterborne disease caused by sewage flowing into Lake Michigan—the source of Chicago's drinking water. But today it could serve as an entryway for invasive Asian carp.

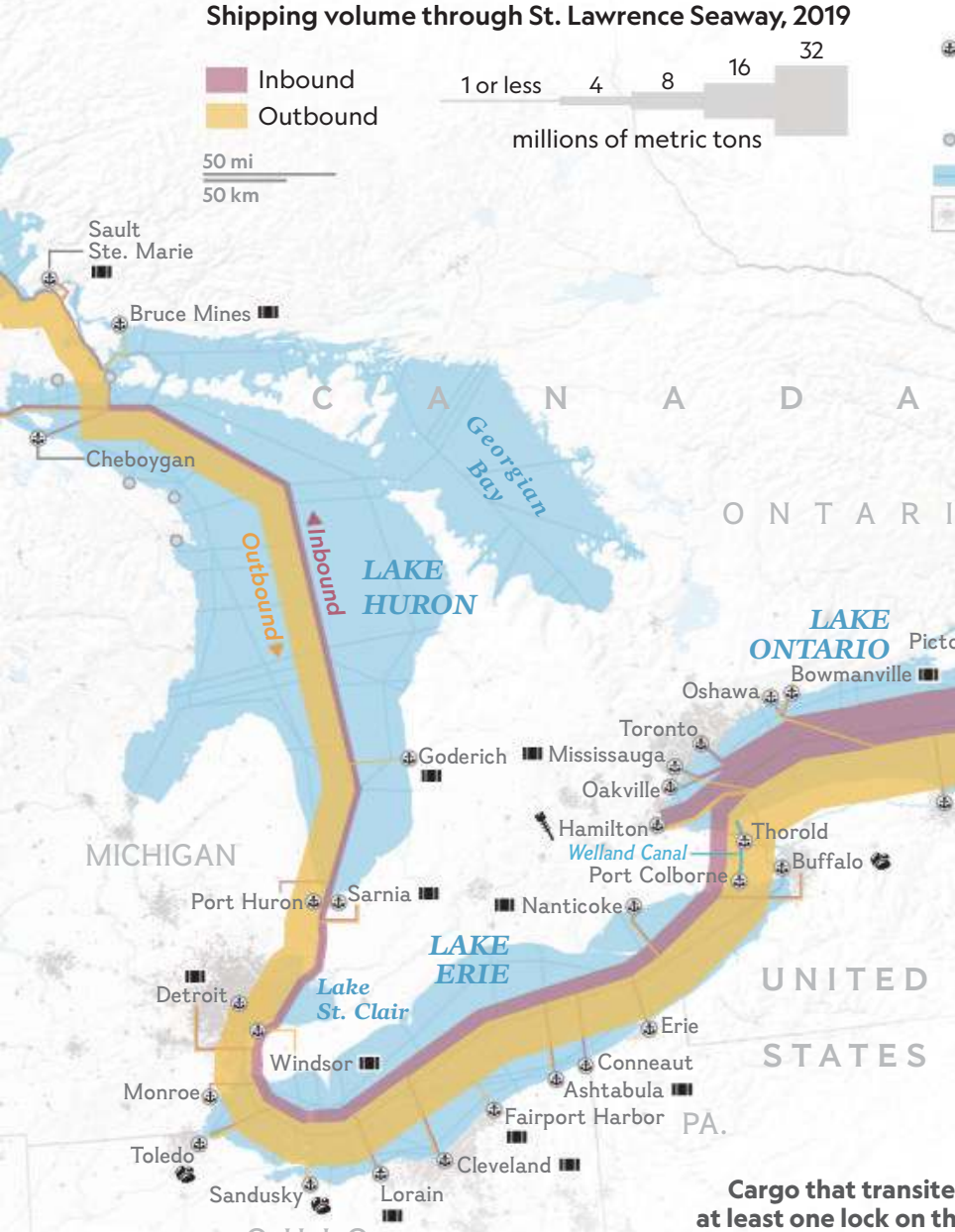
Today
The Panama Canal system became the default size for ocean shipping; this left the smaller Welland Canal with limited international trade.

MATTHEW W. CHWASTYK AND JASON TREAT, NGM STAFF; KELSEY NOWAKOWSKI
SOURCES: GREAT LAKES ST. LAWRENCE SEAWAY SYSTEM; U.S. DEPARTMENT OF TRANSPORTATION; USGS; ST. LAWRENCE SEAWAY MANAGEMENT CORPORATION AND SAINT LAWRENCE SEAWAY DEVELOPMENT CORPORATION; PANAMA CANAL AUTHORITY

Length of shorelines in the contiguous United States



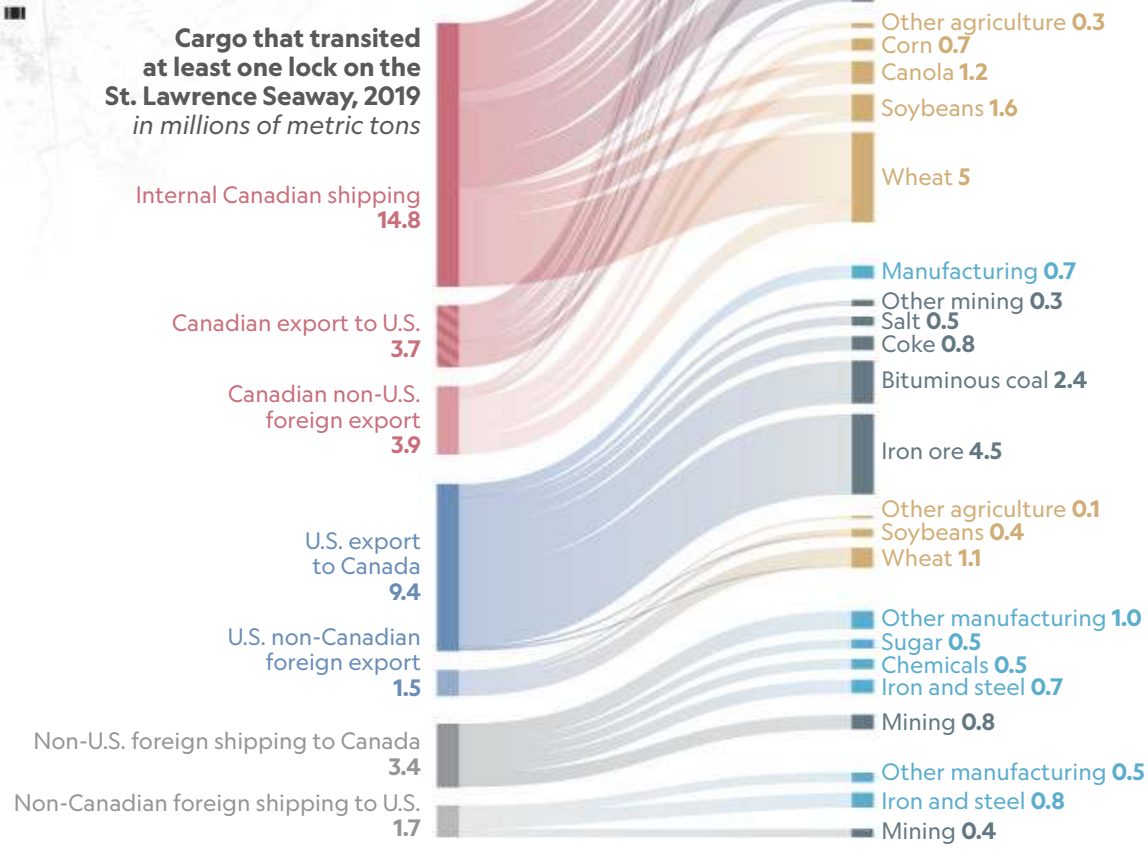
Shipping volume through St. Lawrence Seaway, 2019



WHAT GETS SHIPPED ON THE SEAWAY

Canada relies heavily on the St. Lawrence Seaway for domestic and international trade, principally of agricultural products. The U.S. uses the seaway mostly to export mineral products, such as iron ore and coal, to Canada.

Cargo that transited at least one lock on the St. Lawrence Seaway, 2019
in millions of metric tons



LAKE MICHIGAN

Beneath Chicago, work continues on one of the world's largest civil engineering projects: the city's Tunnel and Reservoir Plan. Designed to reduce flooding and prevent raw sewage from discharging into Lake Michigan, the system is expected to be fully operational by 2029.

runoff. The biggest problem is caused by these megafarms, especially CAFOs. This is not mom-and-pop farming."

CAFOs, concentrated animal feeding operations, are essentially factories for raising animals—a pig, poultry, and beef industrial complex. When the number of animals on a CAFO exceeds EPA limits, the CAFO must comply with clean water laws, but many operate just under the legal limits and escape regulation. A recent study found that from 2005 to 2018, the number of farm animals in the 8,300-square-mile Maumee watershed, the largest in the Great Lakes, more than doubled from nine million to 20 million. The amount of manure applied to fields during that same period—a rich source of phosphorus—increased by about 40 percent.

Without more stringent restrictions on phosphorus runoff, algal blooms will become a permanent fixture of Lake Erie. One scientist told me that if current trends continue, the occurrence of blooms will double by 2040. "This is not a money problem," Kapszukiewicz said. "It's an accountability problem. All the money in the world isn't going to solve it without accountability."

THE LAKES' IMMENSITY belies their fragility. Over the course of several months I visited all the lakes except Huron. Being young, in geological terms, they're not as ecologically diverse as the oceans; they're immature, more susceptible to threats. Each lake deserves its own story: Michigan and Huron, which are in effect two lobes of a single lake, have the opposite problem from Lake Erie: They're too clean.

Hundreds of trillions of invasive mussels have nearly denuded their waters of plankton; the mussels can filter the amount of water in Lake Michigan in a week or less. Mercury and PCB levels in the Lake Ontario watershed are so high that many fish there are unsafe to eat. I met with dozens of researchers who have devoted entire careers to understanding and protecting the lakes. Charter boat captains told me how algal blooms have gutted their livelihood. And I learned that harmful algal blooms have started to appear on Lake Superior, the least spoiled of the lakes.

So where does that leave us? The fate of the lakes—and of the millions of people who depend on them—might best be described by an Anishinaabe word: *zaasigaakwii,* which has no real English equivalent.

"It refers to birds arriving in spring, then [they're] hit by a big storm," says Michael Wassegijig Price, a traditional ecological knowledge specialist at the Great Lakes Indian Fish and Wildlife Commission. "It's what happens when you get hit with the unexpected in nature." Like multiple 500-year storms in a decade or algal blooms on a northern lake.

Eighteen years ago Tom Borg had his own experience of zaasigaakwii. On a February day he drove his snowmobile onto the frozen lake near his home, something he'd done on countless other winter days. He wasn't far from the forested shore when the ice suddenly gave way beneath him. Luckily the water was only three feet deep—"but just as darn cold as 30 feet," Borg said. "The pain was extreme, like daggers into my

HOW TO HELP

The Nature Conservancy works with farmers to reduce the flow of phosphorus into the Great Lakes by planting cover crops and other practices. *nature.org*

Friends of the Detroit River is restoring waterways and land in Michigan and Ontario, with a focus on the Detroit River. *detroitriver.org*

The Ojibwe (an Anishinaabe tribe) consider wild rice sacred and have grown it for centuries. Purchasing it from the tribe injects cash into the local economy and helps promote sustainable development. *LLwildrice.com*

LAKE MICHIGAN

The Coast Guard Festival in Grand Haven, Michigan, started as an informal picnic for Coast Guard families in 1924. It now draws crowds of 350,000 every summer, with concerts, ship tours, and fireworks. The tradition was interrupted in 2020, when the pandemic forced the event's cancellation.

MORGAN HEIM

legs." Somehow he managed to pull his snowmobile from the lake and drive back to his cabin, where he started a fire that warded off certain hypothermia. "If it wasn't for my grandfather's teachings to keep my wits about me and don't panic, I might not have survived."

On a cool September morning, Kama Bay, an inlet on the northern edge of Lake Superior, looks serene, untainted—not endangered by anything at all. It soon vanishes from view as Borg and I ascend a steep, maple-lined trail off the inlet's shore. Some maples seem to glow, the season's alchemy turning their leaves flame red. We pass a stream and small waterfall, whose waters would soon reach the Anishinaabe's Great Lake and eventually spill over Niagara Falls. With each step up the trail, the threats to the continent's five freshwater seas momentarily recede, becoming problems of some other world, some other time.

Borg pauses and suggests that I take a maple leaf home as a gift from the watershed, a talisman as fragile and lovely as the lake below us. Later, reflecting on the day he almost died from exposure, he said that perhaps he hadn't been as careful as he should have been—maybe he could have looked more closely at the ice, maybe he would have seen the danger ahead. "Nature isn't mean," he said. "It's unforgiving." □

Tim Folger wrote about the Arctic's dwindling sea ice in the January 2018 issue. **Keith Ladzinski** photographed America's changing national parks for the December 2016 issue.

Story and photographs by

HANNAH REYES MORALES

Songs to Soothe

In cultures around the world, the lullabies that coax children to sleep are windows into parents' hopes, fears, and dreams for the future.

MONGOLIA

Altanzul Sukhchuluun and her daughter, Khulan, snuggle at bedtime in Ulaanbaatar. Altanzul is a nurse at a family clinic in her district, where she tends to women and children living in communities with the most polluted air in the country.

THE TIM HETHERINGTON TRUST PROVIDED SUPPORT FOR THE PHOTOGRAPHS IN THIS STORY.

TURKEY

Syrian girls play with dolls before bedtime in the Boynuyogun refugee camp in Hatay Province. It's too hot to play outside during the day, so the girls take afternoon naps and move to the playground in the evening.

UNITED STATES

Xavier Zakrajsek, six, hugs his doll with toy hearing implants in Ayer, Massachusetts. Xavier is deaf and uses cochlear implants to help him hear. After singing a lullaby, his mother, Jessica, says “I love you” out loud every night in case the implants fail. “I make sure to tell him in case it is the last thing he hears.”

The song comes alive as night draws in. Hear it curl beneath the blanket, slip between the fold of cradling arms, in rooms across the world. To an audience of children, a hidden chorus of caregivers fills the night with song. They're singing lullabies.

PHILIPPINES

Amy Villaruel puts her daughter Jazzy to bed in Bataan Province. For the Villaruels, who rely on spearfishing for their income, bedtime is dictated by the tides. Amy's husband and sons often fish at night.

LISTEN TO AMY'S LULLABY ON YOUTUBE.
Use your phone's camera to scan the QR codes in the story to hear lullabies from around the world.

For Khadija al Mohammad, nighttime has always been the time for silence, comfort, and quieting the noises of the day. When her eldest son, Muhammed, was born 19 years ago, a decade before the Syrian civil war, she sang sweet lullabies—songs passed down by her mother and grandmother, songs of heritage and place.

As the conflict escalated, her family left their home in Kafr Nubl in 2013 and made a reluctant crossing to Turkey, where her youngest child, Ahmad, three, was born.

Khadija's lullabies have changed with her journey. A schoolteacher and mother of five, she is among 12 million displaced from Syria since 2011, the result of a conflict that has killed probably more than a half million people.

Khadija, now a Turkish citizen, is like many mothers around the world, nurturing children and soothing them with lullabies in environments fraught with hazards. Sung in our most intimate spaces as our days come to a close, these songs hold far more than their function. As situations change, lullabies help to establish safe spaces for children. Today, amid sweeping changes driven by the COVID-19 pandemic, lullabies endure as an especially important way to preserve tender moments between parents and their young children.

SUNG ACROSS CULTURES, lullabies echo the histories of those who sing them. Khadija's lullabies

NGM MAPS

TURKEY

Songs reflect a time of upheaval

Khadija al Mohammad puts her son Ahmad, three, to bed in their home in Şanlıurfa. Khadija's family fled Syria in 2013. She recalls how her lullabies evolved from the sweet traditional songs that she sang to her older children to today's lullabies about war and migration.

'I placed you in the loft to sleep, but I feared the snake.'

LISTEN TO A SYRIAN REFUGEE'S LULLABY.

RIGHT

Sedil al Mohammad, 12, here looking from her home's rooftop, often asks her mother, Khadija, about life in Syria. Khadija says she sings songs from Syria to give her children a sense of their homeland.

BELOW

Pigeons fly above the city of Hatay at dusk. Hundreds of thousands of Syrians have found refuge in this area near the Syrian border. Turkey has the world's largest population of refugees, including 3.6 million Syrians who have fled conflict at home.

LISTEN TO A 4,000-YEAR-OLD LULLABY.

became songs about the war. "My children knew about my feelings," she muses. From their tent in a resettlement camp to their home in an apartment in Şanlıurfa, nightmares have followed Khadija. She dreams of helicopters and of the Syrian army following her, and she wakes up worrying about her children. They huddle around her when they see her in tears. By a mattress on the floor, she gently lays Ahmad down on her legs, rocks him slowly, and sings.

"Ohh aircraft, fly in the sky and do not strike the children in the street. Be tender and kind to these children."

A Babylonian lullaby that's about 4,000 years old was found inscribed on a clay tablet. By the glow of a phone or to the thrum of a city, lullabies still charm babies to sleep today. We inherit them, and we pass them on. We carry lullabies across borders and make new ones along the way. They contain the traces of those who came before us, and they will carry traces of us long after we're gone. Within these songs we've expressed not just our greatest fears, but in the same breath, our hopes and prayers. They are likely to be the first love songs children hear.

Like many lullabies around the world, Khadija's song is a response to the pressures of the day. And although lullabies sound soothing and reassuring, their lyrics often are dark and far from comforting—they're a window into our fears. The Icelandic lullaby "Bíum, Bíum, Bambaló" is haunted by a face at the window. The Russian "Bayu Bayushki Bayu" warns to stay away from the edge of the bed or a little gray wolf will drag a baby into the woods and under a willow bush.

As lullabies hold our fears about a world that's often unforgiving and cruel, these songs don't always shield us from it. "Rock-a-Bye, Baby," one of the most well-known English-language lullabies, is after all a song about a cradle falling from a treetop, baby and all.

But lesser known are the lyrics of a modern, longer version. *"Rock a bye baby / do not you fear / Never mind baby / Mother is near"* begins the last stanza. Lullabies reveal our fears, but perhaps more importantly, they are a reflection of our reassurances. *"Now sound asleep / until morning light,"* it concludes.

The nonprofit National Geographic Society helped fund this article.

IN JAPAN THE "Itsuki no Komoriuta," or "Lullabies of Itsuki," are the songs of young girls who were sent to work as live-in nannies for wealthier families in the village of Itsuki during the century before WWII. *"Nobody will shed tears when I die. Only cicadas on the persimmon tree will cry"* are lyrics from a well-known Itsuki lullaby.

A few years ago, in the Philippines, I sang a lullaby for the first time to my stepson, who was four years old at the time. The apartment my husband and I had moved into in Manila's business district was new to him and a wearisome boat ride away from his mother and his home by the seaside on the island of Mindoro. He was frightened when the lights went out. As he started crying, I was sure I was doing everything terribly wrong, denting a relationship that is precious and delicate to me. In panic, I carried him and began to sing "You Are My Sunshine." On that warm summer night he fell asleep, his tears drying to the hum of the fan. But whose fears had I been assuaging?

LIBERIA

Shared storytelling in the evening

Children gather around Patience Brooks, who holds her younger daughter, Marta, in her lap in Mamba Point, Monrovia. Mothers and children in her neighborhood take turns telling stories as they prepare dinner for their families.

'Sleep, baby, sleep. Momma want to see you sleepy. And then when you sleepy, Momma feel so fine.'

LISTEN TO PATIENCE'S LULLABY.

THERE IS A GROWING BODY of research about how lullabies help soothe both caregiver and child. Laura Cirelli, professor of developmental psychology at the University of Toronto, studies the science of maternal song. She found that when mothers sang lullabies, stress levels dropped not just for the baby but for mothers as well. In her most recent work, she found that familiar songs soothed babies the most—more than speaking or hearing unfamiliar songs.

A new mother herself, Cirelli sees singing lullabies as a "multimodal experience" shared by mother and child. "It's not just about the baby hearing music," she says. "It's about being held by the mom, having her face very close, and feeling her warm, gentle rocking."

From culture to culture, lullabies "tend to have collections of features that make them soothing or calming," says Samuel Mehr, director of Harvard University's Music Lab, which studies how music works and why it exists. The lab's project, the Natural History of Song, found that people can hear universal traits in music—even when they are listening to songs from other cultures. The project asked 29,000 participants to listen to 118 songs and identify whether it was a healing song, a dance song, a love song, or a lullaby. "Statistically, people are most consistent in identifying lullabies," he says.

In a separate study, Mehr's lab found that even when infants were listening to lullabies that were not sung by their own caregiver, or were not from their own culture, they were still soothed. "There seems to be some kind of parenting-music connection that is both universal around the world but also old, sort of ancient. This is something that we've been doing for a really long time."

The earliest complete record of a lullaby begins, "Little baby in the dark house." It tells of a "house god" who, disturbed by the screaming of a baby, darkly calls for the child.

"They were rather brutal about it," says Richard Dumbrill, the director of the International Council of Near-Eastern Archaeomusicology at the University of London who translated the 4,000-year-old tablet from Akkadian script. "And indeed, remember, these were brutal times. Human life was very, very cheap. It is possible that by educating their babies in fear, it would bring them to adulthood with reflexes of defense."

The lullaby as a cautionary tale—sleep, or else—is common across cultures. Many and lurid are the child-snatching, child-snacking beasts that await those who resist sleep. The horror in these visions bypasses those too young to understand. But for older children, including those sharing bed spaces, lullabies—like other forms of folklore—are an important means of broadcasting a picture of the world.

"I SING TO FORGET THE BABY'S PA," Patience Brooks says with a smile after settling her eight-month-old daughter, Marta, to sleep. Bedtime at Patience's home in Monrovia, Liberia, is an animated affair. The Mamba Point neighborhood vibrates with music, the scrape of dinnertime, and conversation. Her nighttime tunes are a blend of song, scat, and beatbox known locally as "lie-lies." Lie-lie songs are creative expressions made up by babies' caretakers to stop them from crying, to put them to bed, or to entertain. Patience drums against Marta's back as the pair bump and sway, and the girl

LEFT

After years of homelessness, Christiana Gmah sings praise songs to her daughter Orinna at her home in the West Point township in Monrovia. Her parents sent her away when she became pregnant at 13 with her first daughter, Georgina. Today she sells tea and bread at night to support her daughters.

BELOW

Dusk descends on the township on the Atlantic Ocean. The impoverished community outside Monrovia's city center is overcrowded and lacks adequate utilities and basic sanitation.

Beloved stuffed animals are displayed in the children's bedrooms that photographer Hannah Reyes Morales visited around the world. Some of the children sang lullabies to their stuffed animals.

falls asleep to her mother's dance.

Sleep, baby, sleep
Sleep, baby, sleep
Momma want to see you sleepy
And then when you sleepy
Momma feel so fine
Momma feel so good
So sleep, sleep
Sleep, baby, sleep

For Patience, a mother of two who gave birth to her first daughter at 13, mothering presents challenges familiar to the estimated three in 10 Liberian teens who have had a baby or been pregnant between the ages of 15 and 19.

In this neighborhood, the spaces outside become communal living rooms as neighbors help with the day-to-day tasks of caring for children. Women take turns watching over dozens of children as they play and share, allowing mothers to prepare dinners for their families and spend time at home in the evening after a workday.

"Once upon a time…" Patience begins, and the children listen. They take turns making up tales and sing songs together. The tiny space fills with the lore of kings and queens. As night falls, the air is charged with musical refrains of magical creatures and adventures in the woods.

Cirelli's research found that children who share synchronous musical experiences with other people are more likely to offer them support. "If you are singing the same songs as your community members," Cirelli says, "it's this cue for kinship and group membership."

Bedtime and lullabies are as diverse as our world. For 10-year-old Zaijan Villaruel, who lives in the Philippines, sleep is dictated by the tides of the sea and his family's needs. At night he fishes with his father and older brothers and falls asleep to the sound of the waves and the motor of the outrigger boat on the way home.

The Philippines is part of the Coral Triangle, with more species of marine life than anywhere else on Earth. Fishing communities like the one where Zaijan and his dad, Umbing Villaruel, live, rely on the sea for sustenance and bear some of the greatest brunt of climate change.

Umbing does not want his sons to become fishermen; catches have dwindled drastically in the past decade from overfishing. But because of the lockdown during the pandemic, Zaijan learned to fish to help provide for his

MONGOLIA

When naps are a break from pollution

Kindergartners from a community near a landfill take a nap in a day care in Ulaanbaatar. Power plants and homes heated with coal cause air pollution to reach hazardous levels. These rooms have air purifiers, which are not available in most homes.

'A lively, busy day is coming to an end. Upon us is a magic tale night.'

LISTEN TO A MONGOLIAN LULLABY

family. "He learned to survive in a time of loss," Umbing says.

During the daytime, Zaijan sings songs he learned from the karaoke machine to his two-year-old baby sister, Jazzy, in their home in the province of Bataan. He rocks her gently back and forth, and she falls asleep to a song about a boy hoping for a girl's tears to dry.

In the Philippines, where I am from, the words *"Tahan na"* are uttered between lullabies. The words often are said to calm a weeping person and translate to "stop crying." But to say "tahan na" is to also say "feel safe," "feel still," and "feel at peace." *Tahanan,* the word for "home" in Filipino, is the place where tears subside.

CARNEGIE HALL, THE HISTORIC MUSIC VENUE in New York City, developed the Lullaby Project in 2011. Based on research that lullabies benefit maternal health, strengthen bonds between parent and child, and aid child development, the project fosters collaborations between professional musicians and new parents to compose personal lullabies for their babies. Since its inception, the project has helped create thousands of lullabies spanning multiple countries, reaching mothers and fathers through hospitals, homeless shelters, programs for young mothers, and correctional facilities. "We are essentially thinking of lullabies as an anchor, in very simple terms, for parents to express their personal hopes, dreams, and wishes for their children and for themselves," says director of Early Childhood Programs Tiffany Ortiz, who oversees the Lullaby Project.

"Many mothers will actively talk about using lullaby songs, chants, as a way of reestablishing home," says Dennie Palmer Wolf, a research consultant for the Lullaby Project. Migrant families in Greece participated in the Carnegie project, and local collaborators describe their lullabies as "portable sanctuaries."

"Like prayers or traditional stories, you can carry them anywhere with you," Palmer Wolf says. "They take no room in your backpack; you can always pack them in. It's a way of establishing continuity where there is almost none."

LULLABIES REFLECT THE PRESENT, but they are often rooted in the past.

In Mongolia the *buuvei* lullaby has been sung by nomads for generations. Its refrain, "buuvei," means "don't fear." "Love is the most important thing—passed on like a heritage," Bayartai

Genden, a Mongolian traditional singer and dancer, and grandmother of 13, tells us as she describes "the magic of giving love to your child through melodies."

Bayartai laments the smog that covers Mongolia's capital, Ulaanbaatar, a barrier between herself and her ancestors. "Our ancestors from the blue sky must be crying because of the air pollution," she says. "The sky used to be blue." Bayartai sings a lullaby to her newborn grandson. An air purifier hums in the background.

In Ulaanbaatar, one of the world's coldest capitals, winter is marked not only by temperatures that can reach minus 20 degrees Fahrenheit but also by toxic air. Coal-burning power plants and families using coal to heat their homes cause hazardous levels of air pollution, sometimes more than a hundred times the safe limit set for fine particulate matter by the World Health Organization.

With more than half of Mongolia's children living in Ulaanbaatar, where pneumonia is the

LEFT

A smog cloud hangs over Ulaanbaatar. Air pollution from coal burning during the winter months is among the worst in the world, leading UNICEF to declare a child health crisis because of increased respiratory infections and lower lung capacity than in children in areas outside the city.

BELOW

Todgerel Lkhamjav (left), Dejid Bayarbaatar (right), and their youngest son, Galanbagana, curl up at bedtime in their home in Nalaikh district outside of Ulaanbaatar. Todgerel worked as a coal miner for 25 years but now is a school security guard. Coal jobs have disappeared as local bans on coal burning have been imposed.


I am bright and I am brilliant.
I can do extraordinary things.
When my hair sparkles and glows,
I can soar without wings.
Princess Truly
SPARKLING CURLS

UNITED STATES

Bedtime routines change during a pandemic

Anthony Hallett reads *Princess Truly in My Magical, Sparkling Curls* to his daughter Ava, six, in Brockton, Massachusetts. Home from work because of the COVID-19 pandemic, Anthony could join in the family bedtime routine.

'Good-night Luke, Good-night Luke. Good-night Luke, it's time to go to bed.'

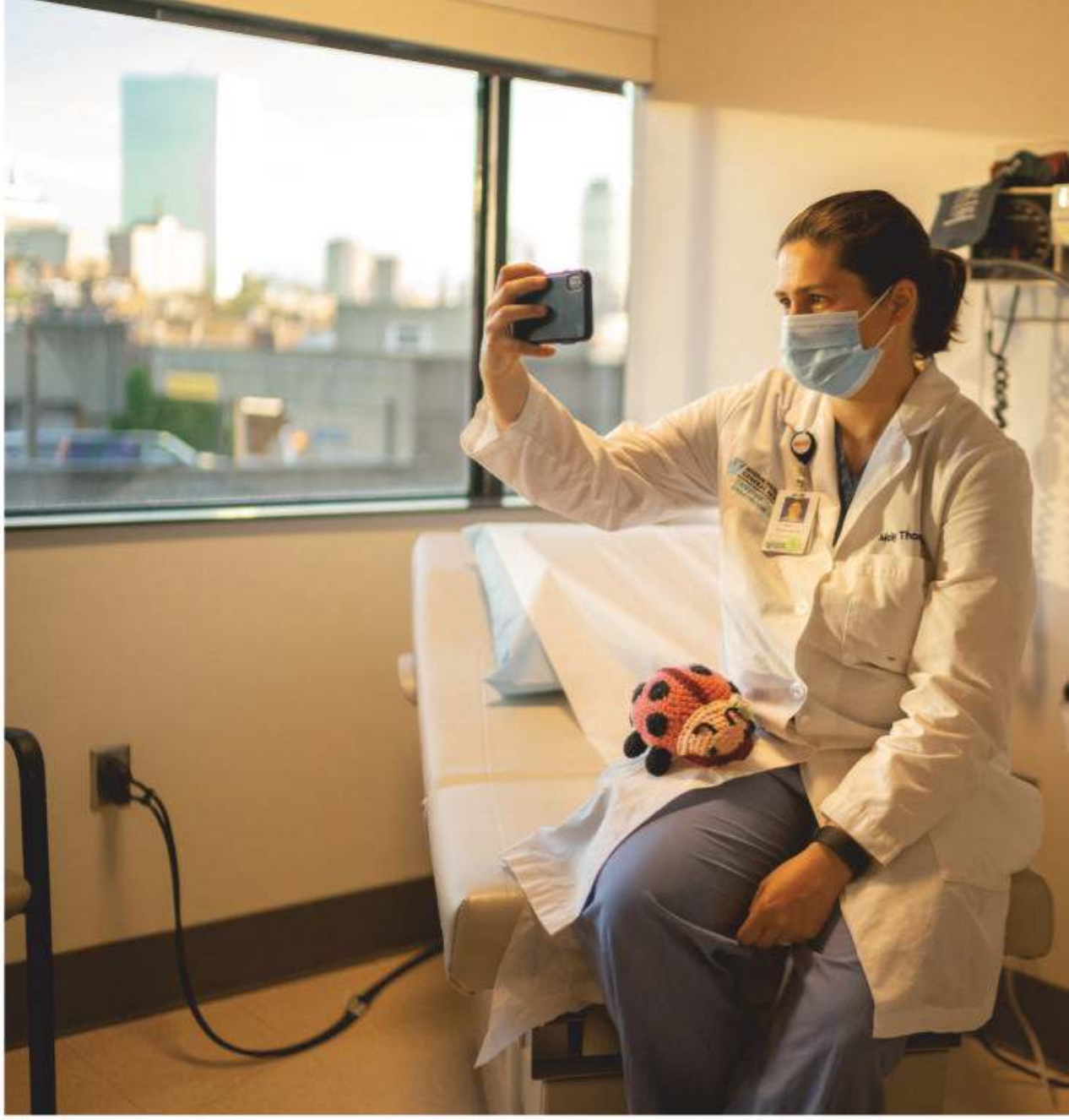
LISTEN TO THE HALLETT FAMILY'S LULLABY

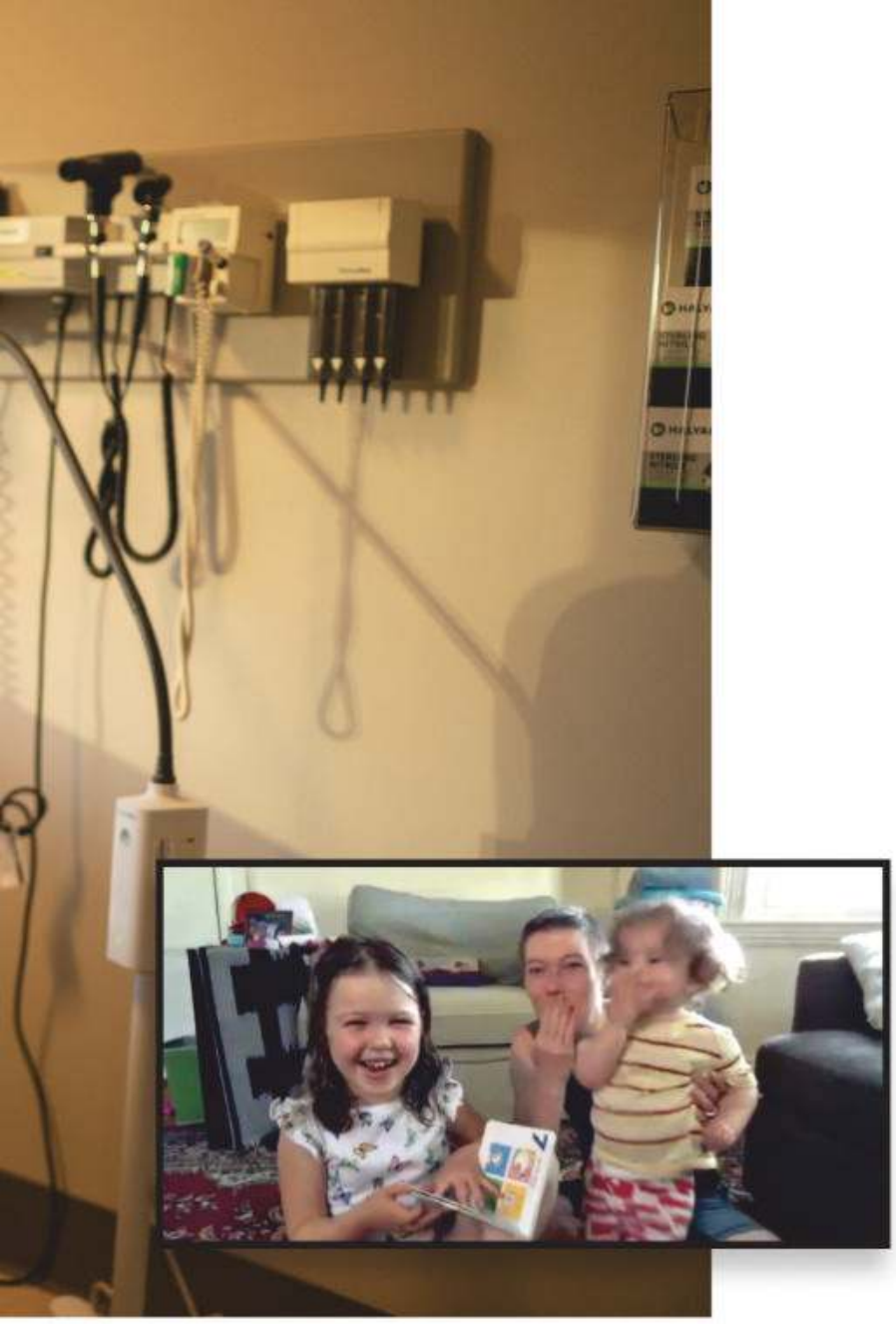
RIGHT

Physician Molly Thomas calls her wife, Hannah Leslie, and their daughters, Ada and Delaney (inset), from Massachusetts General Hospital in Boston, sings the girls a lullaby, and wishes them goodnight from work. Molly isolated from her family during the time that she worked with COVID-19 patients.

BELOW

Allison Conlon, a nurse caring for COVID-19 patients, visits her son Lucas, two, through a glass door at their home in Bridgewater, Massachusetts. Here on a day off, she reads Lucas stories before he takes a nap. Allison says "reading to him each day helped maintain a sense of normalcy."





second leading cause of death of children under age five, UNICEF declared that the city's air pollution has become a child health crisis.

"I use these words to protect my children. They help my children heal," Oyunchimeg Buyankhuu says of the lullabies she sang when her two daughters were often sickened by the pollution. Her family moved out of the city so her children could breathe fresher air. Oyunchimeg sings the traditional buuvei lullaby, but between refrains she whispers healing words, reshaping a long-established song for today.

IN TURBULENT TIMES stories bring us together. As the COVID-19 pandemic began altering life worldwide, physical distancing drastically changed the way we connect. Women make up nearly 70 percent of health and social service workers globally. For mothers working on the front lines of the pandemic, putting themselves at risk to care for their communities comes with the challenge of how best to care for their own families.

Elizabeth Streeter, a nurse in Massachusetts, works on the COVID-19 floor of her hospital. As the pandemic escalated, she made the difficult decision to isolate from her four boys in early April, to avoid exposing them to the virus. She stayed in an RV outside of her parents' home for a month while her husband stayed home to care for their children. During the evenings, Elizabeth connected with her family over the phone. She would sing her three-year-old son's favorite lullaby while fighting through tears, unclear about when she might get to hold him again.

"To separate such a sacred bond between mother and child, there are no words," she says in a journal post on Facebook. For Elizabeth, making her children safe meant being physically present. But to serve her community during the pandemic, that has shifted. These days, living away from her children has become her way of keeping them safe. "It looks entirely different than what I always thought protection looked like."

Allison Conlon, a nurse from Bridgewater, Massachusetts, who works in a hospital's intensive care unit, also separated from her family. At night she called Lucas, two, to read to him and sing "The Wheels on the Bus" and "Itsy-Bitsy Spider" before he went to bed. On Sundays she visited her family's home but did not enter, instead reading stories to him through a glass storm door. From her side of the glass, Allison gave her son a high five and a kiss. "My son was so resilient and adapted to the change very well, and for that I am super thankful," she says.

To sing a lullaby to someone is to make a connection. The songs connect caregiver to child, but perhaps less noticeably, they also tell stories that connect us to our past, and to each other. Bayartai Genden describes the lullaby as "an exchange of two souls."

Lullabies are part of the fabric from which caregivers create safe spaces that are necessary for dreams to unfold. Khadija al Mohammad says Ahmad reaches out for her lullabies "not only to sleep but to feel my tenderness." These songs remind us that we are not alone, and in the dark of night, they seem to hold a promise that on the other side waits the light of morning. □

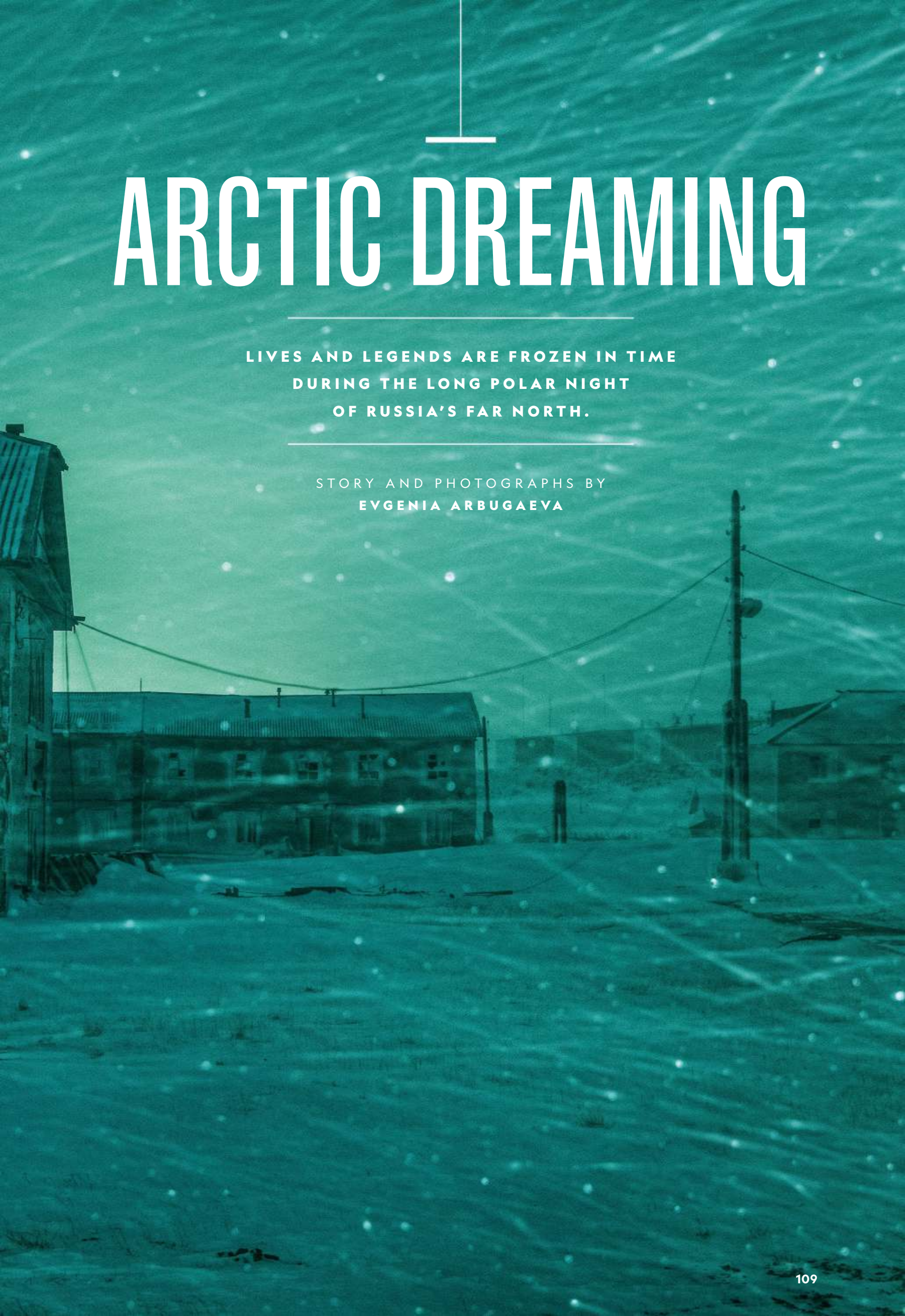
Hannah Reyes Morales is a National Geographic explorer whose work focuses on resilience and human connection. **Rupert Compston,** a musician and sound recordist, contributed reporting and produced audio for this story.

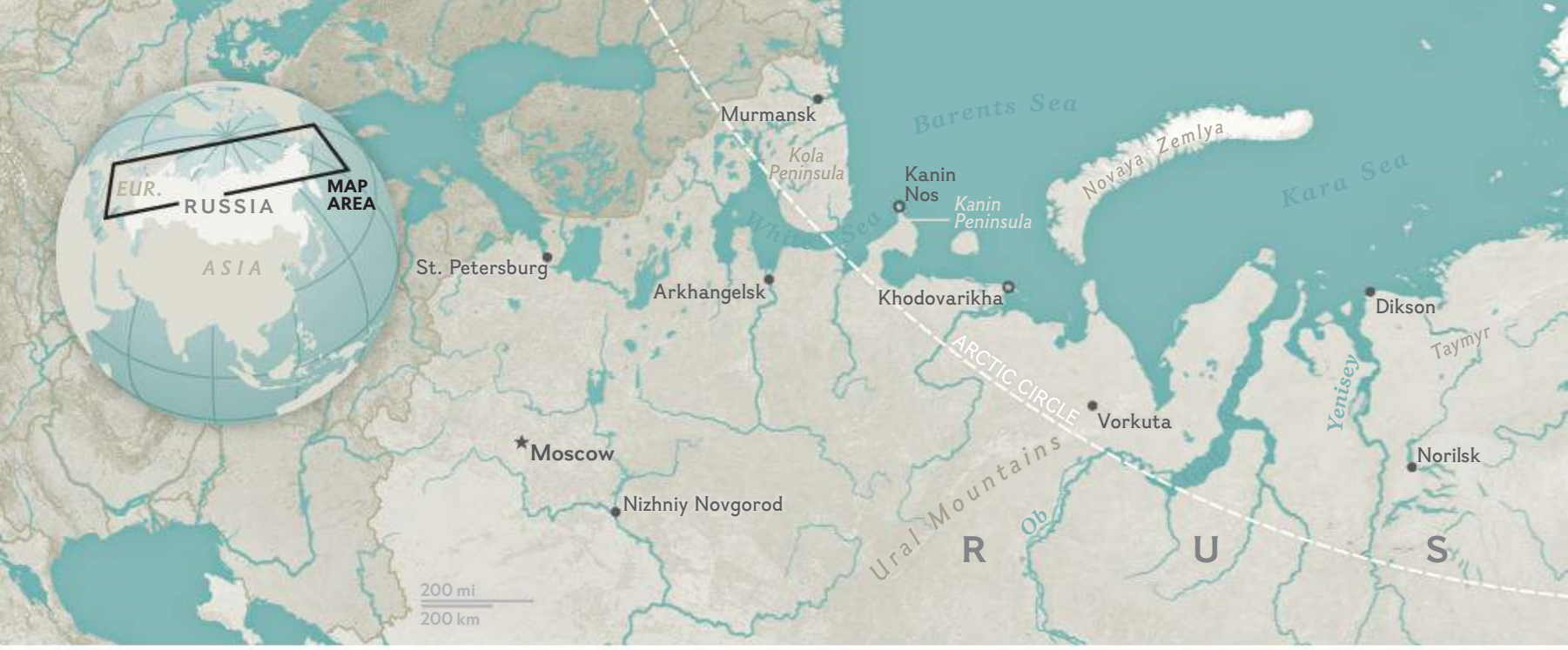
Wind-blown snow swirls past abandoned buildings keeping cold vigil over the empty streets of Dikson. Once the centerpiece of Soviet dreams to develop the Arctic, the port town was slowly deserted after the collapse of the Soviet Union in 1991.

ARCTIC DREAMING

LIVES AND LEGENDS ARE FROZEN IN TIME DURING THE LONG POLAR NIGHT OF RUSSIA'S FAR NORTH.

STORY AND PHOTOGRAPHS BY
EVGENIA ARBUGAEVA





PEOPLE SAY THAT ONCE you have the Arctic in your system, it will always be calling you. I spent my childhood running about the tundra and watching the northern lights as I walked to school in the polar night, the poetic name for the two months of darkness that's not just winter here but also a state of mind. I left my hometown of Tiksi, a remote seaport on the shore of Russia's Laptev Sea, years ago to live in big cities and different countries. But the Arctic has been calling me back. I crave its isolation and slower pace of life. In this frozen northern landscape, my imagination flies like the wind, with no obstacles. Every object becomes symbolic, every shade of color meaningful. I am my real self only when I am here.

It's much the same for those I photograph. Sometimes I think their stories are like chapters in a book, each revealing a different dream but each also connected to a love of this land. There's the hermit who imagines he's living on a vessel at sea, and the young woman who dreamed of living with her beloved at the edge of the world. Then there's the community that's keeping its past and future alive as its members follow the traditions and retell the myths of their ancestors. And finally there's the old Soviet dream of polar exploration and conquest. Each dream has its own color palette and atmosphere. Each person who is here is here for a reason.

The first dream belongs to Vyacheslav Korotki. He was the longtime chief of the Khodovarikha Meteorological Station on an isolated peninsula on the Barents Sea—a slender, barren spit of land that, Korotki says, feels like a ship. When I first met him, I instantly recognized his tarpaulin jacket, the kind all men wore back in Soviet times in my hometown. He is what is known as a *polyarnik*—a specialist of the polar north—and has dedicated his life to work in the Arctic. He still helps report the weather.

Outside the station I could hear ice shifting and grinding and the wind making the radio wires whistle. Inside it was quiet, with only Korotki's footsteps and a squeaking door marking the passage of time. Every three hours he'd leave, then return, muttering observations to himself—"Wind south southwest, 12 meters per second, gusts up to 18 meters, getting stronger, pressure falls, snowstorm is coming"—which he would then report over a crackling old radio to a person he has never seen.

One day I felt sad, the polar night causing my thoughts to run in chaotic directions. I came to Korotki with a cup of tea and asked how he could live here, alone, every day the same. He told me: "You have too many

The nonprofit National Geographic Society helped fund this article.

expectations, and I guess it's normal. But every day is not the same here. Look, today you saw the bright aurora borealis and a very rare phenomenon of thin ice covering the sea. Wasn't it great to see the stars tonight, after they were hiding from us behind the clouds for over a week?" I felt guilty for gazing too much inside of myself, forgetting to observe outside. From then on I became all eyes.

One month I lived with a young couple, Evgenia Kostikova and Ivan Sivkov, who were collecting meteorological data at another frozen edge of Russia. Kostikova had asked her beloved Sivkov to join her up north after their first year together in a Siberian city. They monitored the weather, chopped wood, cooked, tended the lighthouse, and looked after each other. For medical help they relied only on a distant helicopter, but it could be delayed for weeks in rough weather. Kostikova called her mother almost every day, but as there was little news to report, she'd often ask her mother to leave the phone on speaker and to go about her housework. Kostikova would just sit and listen to the sounds of her faraway home.

Perhaps partly because of their isolation, the 300 Chukchi in the village of Enurmino have kept their traditions, living off the land and sea as their ancestors did, hewing to the same myths and legends passed through the generations. It is an honor to be a hunter, and the villagers follow federal and international quotas as they hunt for walrus and whale to sustain their community through the long winters. Not far from Enurmino, I spent two weeks in a wooden hut with a scientist who was studying walruses. We were trapped inside for three of those days, careful not to set off a panic among the estimated 100,000 walruses that had hauled out around us, their movements and fighting shaking our hut.

The dream of Soviet greatness is covered in frost in Dikson, on the shore of the Kara Sea. During its heyday in the 1980s it was called the capital of the Russian Arctic, but since the demise of the U.S.S.R. it has become almost a ghost town. Perhaps there will be new towns as the region warms, but it pains me to see the failure of human effort on such a scale.

During my first weeks I was disappointed with the photos I shot in Dikson's endless darkness, but then the aurora borealis suddenly exploded in the sky, coloring everything in neon hues for several hours. Cast in a green light, a monument to soldiers looked like Frankenstein's monster, who, after all, at the end of Mary Shelley's book, escaped to the isolation of the Arctic. Then the aurora faded, and the town started to slowly disappear back into darkness until finally it was invisible. ▯

Evgenia Arbugaeva was born in Tiksi, in the Russian Arctic. She recently photographed the Indonesian butterfly trade for the magazine.

CHRISTINE FELLENZ, NGM STAFF. SOURCE: GREEN MARBLE

KHODOVARIKHA | 68.941° N | 53.769° E

ON A QUIET AND WINDLESS DAY,

Vyacheslav Korotki drifts alone in his handmade boat on a narrow bay of the Barents Sea near the Khodovarikha Meteorological Station. He has spent most of his life in remote Arctic stations and says he loves this particular area he's called home for two decades.

KHODOVARIKHA | 68.941° N | 53.769° E

CLOCKWISE FROM TOP LEFT

Korotki walks toward a lighthouse that went out of service over 10 years ago. When he ran short of firewood, he'd pry away the lighthouse's timber panels to heat the weather station where he lived and worked. That station has since been replaced with a newer facility.

This radio at the old weather station transmitted meteorological data such as temperature and precipitation to the station in the closest city, Arkhangelsk, nearly 500 miles away. Korotki continues to report meteorological data every three hours, night and day.

A lighthouse model that Korotki is building from matches seems to cast a shadow of the Arctic landscape against the wall of the weather station. The little lighthouse rests atop a Soviet reference book called *The Dynamics of Sea Ice*.

Kesha the parrot, a New Year's gift from photographer Evgenia Arbugaeva, keeps Korotki company as he eats lunch at the old weather station. Kesha is named after a bird in a popular Soviet-era cartoon series.

KANIN NOS | 68.657° N | 43.272° E

'I BROUGHT TREATS LIKE CHOCOLATE AND FRUIT,'

Arbugaeva says. "These little things are like gold in the Arctic and brought the biggest smile to [meteorologist and lighthouse keeper] Evgenia Kostikova's face. She wrapped the apples one by one in newspaper, as if they were made of crystal, to prevent them from freezing."

KANIN NOS | 68.657° N | 43.272° E

CLOCKWISE FROM TOP LEFT

"The edge of the world"—that's what meteorologist and lighthouse keeper Ivan Sivkov wrote in white paint on this storage shack. It sits near where an icebreaker docks to deliver supplies to the Kanin Nos lighthouse and meteorological station every summer.

Kostikova and Sivkov, joined by their dog, Dragon, collect water samples to measure the salinity of the seawater surrounding the narrow Kanin Peninsula, where the White Sea and the Barents Sea meet.

The couple make their way toward the lighthouse, which seems to rise in the air in the midst of a blizzard. It is one of the few remaining lighthouses in the Arctic. New sea routes are opening, and many ships today have modern navigation systems.

Kostikova keeps warm by a small radiator as she reads her book. When Kostikova was a little girl, a family friend told her stories of Arctic life. At 19 she began work at her first polar station. She says she instantly knew that the Arctic was the right place for her.

ENURMINO | 66.954° N | 171.862° W

‘WHEN WE WERE SURROUNDED BY WALRUSES,

the hut was shaking,” Arbugaeva says. “The sound of their roaring was very loud; it was hard to sleep at night. The temperature in the hut was also raised dramatically because of the walrus body heat outside. At this massive Pacific walrus rookery, so many had hauled out on shore—about 100,000—because the warming climate meant less sea ice for them to rest on.”

ENURMINO | 66.954° N | 171.862° W

CLOCKWISE
FROM TOP LEFT

Nikolai Rovtin is lost in thought after speaking of his wife, who passed away last year. He now lives alone at an abandoned weather station. Before the Soviets attempted to develop the Arctic, he lived in a *yaranga,* a traditional Chukchi home of wood and reindeer skin.

A walrus skull rests on a table in a hunter's garage. Walrus meat is a primary means of sustenance for the Chukchi community, which, local hunters say, is allowed an annual quota of walruses and whales. Hunters use traditional harpoons as well as modern guns.

Vika Taenom wears a customary Chukchi dress called a kamleika as she rehearses a traditional dance in the cultural center in Enurmino. Many dances mimic animal movements, and this one is meant to conjure birds such as geese, ducks, and seagulls.

Night falls as Chukchi hunters head home after harpooning this gray whale for its meat. On the return voyage, by tradition, the hunters are silent, speaking only in their minds and only to the whale, asking forgiveness and explaining why the hunt was necessary.

DIKSON | 73.507° N | 80.525° E

‘I IMAGINED THE MUSIC PLAYING AND THE STARS

sparkling in unison after I first entered the quiet room,” says Arbugaeva. “But then I began to hear the wind slamming doors in the corridor and strange creaking sounds. In my fuzzy imagination I thought I heard someone’s footsteps … and I ran.”

DIKSON | 73.507° N | 80.525° E

CLOCKWISE FROM TOP LEFT

The aurora borealis, or northern lights, casts a colorful spell over a monument in this abandoned town square in Dikson. The statue honors the soldiers who defended the once thriving outpost against a German attack during World War II.

The children who last attended school here are now adults, but their textbooks still lie open, seemingly frozen in time. Arbugaeva waited through two weeks of darkness and stormy weather until the aurora borealis provided enough light for photographs.

The cultural center, once alive with performances and celebrations, has long stood empty. Its Soviet architectural style can be found in other Arctic outposts developed during the push to build infrastructure along the Northern Sea shipping route.

A homemade doll leans against a frosty windowsill of an abandoned school in Dikson. In its heyday in the 1980s the town was a symbol of Arctic ambitions and home for a population of about 5,000.

Tens of thousands of Africans die from snakebites each year. Getting treatment can be difficult, and antivenoms are in short supply. It's a health crisis.

Bites That Kill

STORY AND PHOTOGRAPHS BY **THOMAS NICOLON**

Simon Isolomo awoke around 5 a.m., said goodbye to his wife and seven children, and climbed into his dugout canoe. That Tuesday in December 2018 had begun like many others in Isolomo's 30 years of fishing in the province of Équateur, in the Democratic Republic of the Congo. Paddling on the Ikelemba River toward his fishing camp with a couple of friends, Isolomo, a 52-year-old French teacher, snacked on *kwanga*, a popular manioc dish, and enjoyed the cool morning air.

Three hours later they arrived at the camp, and Isolomo began checking the fishing lines he'd set up the day before. Feeling resistance on one, he thrust his hand into the murky water.

A sharp pain sent him reeling. Blood oozed from two puncture wounds on his hand. Just below the surface, a yellowish snake with black rings—probably a banded water cobra—slithered from view.

Isolomo's companions helped him into the canoe and paddled frantically back to their village of Iteli. By the time they arrived, about three hours after Isolomo was bitten, he was slipping in and out of consciousness.

"His eyes had changed color, and he was vomiting," his wife, Marie, recalls, starting to cry. After a traditional healer applied a tourniquet, they set out by canoe for the hospital in Mbandaka, the provincial capital, some 60 miles away. But before they arrived, Isolomo stopped breathing and died.

Isolomo's story encapsulates the global snakebite crisis: Bitten in a remote area, hours from the closest hospital, he didn't have a chance.

As many as 138,000 people around the world die from snakebites each year, according to the World Health Organization (WHO), and roughly 95 percent of those deaths occur in poor, rural communities in developing nations. Another 400,000 people survive with amputated limbs and other permanent disabilities.

One of the worst-hit locations is sub-Saharan Africa, where up to 30,000 deaths from snakebites are believed to occur each year. But some doctors and snakebite experts say the true toll may be double that. A major factor is a severe shortage of the only medicine that can neutralize the toxins of dangerous snakes: antivenom. Complicating matters is that many victims, for lack of money or transportation, or because of distrust of Western medicine, don't go to hospitals—or don't get there in time. Staff at many health centers are insufficiently trained to treat snakebites, and even if the drug is on hand, it's too expensive for many

The nonprofit National Geographic Society helped fund this article.

LEFT

Herpetologist Mamadou Cellou Baldé stands amid the snake collection at the Guinean Institute for Applied Biological Research's snakebite treatment clinic in Kindia, Guinea.

BELOW

Markings on Baldé's hand show the progression of swelling within 30 minutes of his being bitten by a puff adder. Baldé was injected with six vials of Inoserp Pan-Africa antivenom, but he refused painkillers "to better understand what patients feel."

PREVIOUS PHOTO

Flicking its tongue, a bush viper sniffs its surroundings. Venomous snakes kill some 30,000 people in sub-Saharan Africa each year, but many deaths go unrecorded. The real number may be double that.

Patient Abdourahmane Diallo, 12, and his father (at right) wait at Baldé's treatment center, a rare African facility with snakebite expertise. An unidentified snake bit Abdourahmane's left ankle while he was herding goats. The Diallos arrived in Kindia four days later, and the boy was treated successfully.

More than 100,000 people die each year from snakebites. About 95 percent of those deaths occur in poor, rural communities in developing nations.

CLOCKWISE FROM TOP LEFT

Agile and arboreal, the eastern green mamba is one of four African mamba species. Mamba strikes can release a neurotoxic venom that acts quickly, paralyzing respiratory muscles and causing death by asphyxiation.

It's easy to accidentally step on a Gaboon viper, which is masked by perfect camouflage and often lies still on the forest floor for hours. This large viper's venom interferes with blood coagulation; victims who live may require limb amputation.

A forest cobra flares its hood in a defensive posture. Africa's cobras adapt well to human habitats, including fruit plantations and suburban neighborhoods.

Slow moving and nocturnal, the rhinoceros viper is difficult to spot among fallen leaves.

victims. Additionally, most of the more reliable African antivenoms need to be kept refrigerated to stay stable and effective. With frequent power cuts, even in cities, keeping them cold can be nearly impossible.

To draw attention to the snakebite crisis and to attract funding for research and treatment, in 2017 WHO added snakebite envenomation to its roster of neglected tropical diseases, which includes rabies, dengue, and leprosy. In 2019 it announced a goal of slashing the number of annual deaths and disabilities from envenomation by 50 percent by 2030—an undertaking that could cost nearly $140 million.

Elevating snakebites to this level of concern will serve as a wake-up call to Africa's health ministers, says Mamadou Cellou Baldé, 66, a Guinean biologist and research director at the Guinean Institute for Applied Biological Research (IRBAG), in Kindia, which runs a snakebite clinic. Baldé and other experts have long tried to alert authorities to the severity of this deadly crisis and the desperate need for antivenom research and development—with little success.

"We see millions being spent to rig even local elections, while in the meantime African scientists lack money to do lifesaving research," Baldé says.

MOST AFRICAN SNAKEBITE victims are farmers who work in remote fields barefoot or in sandals, making them particularly vulnerable. Once a venomous snake strikes, a race against the clock begins. Transport to the nearest hospital can take hours, even days. By then it may be too late.

The venom of elapids, a family of snakes that includes mambas and cobras, can kill within hours. Their neurotoxins rapidly paralyze respiratory muscles, making breathing impossible. The venom of vipers, however, can take several days to kill, interfering with clotting and leading to inflammation, bleeding, and tissue death.

Once the victim is at a treatment center, survival depends on two vital points: Is a reliable antivenom available? And if so, does the medical staff know how to administer it? Often in sub-Saharan Africa the answer to both is no.

Some people aren't taken to a hospital at all. Families may seek help instead from a traditional healer, who may apply leaves or ash from burned animal bones, or tie a tourniquet around the bitten limb, which can dangerously restrict blood flow. Some botanical treatments do ease pain and reduce swelling, but they can't save a victim's life, Baldé says.

Even so, snakebite survivors may credit traditional healers with saving their lives. About half of the bites from venomous snakes are dry, with no venom injected, says Eugene Erulu, a physician at Watamu Hospital in southern Kenya, "so these patients get well, and the traditional healer believes that he has healed the patients."

ABOUT 25 YEARS AGO Baldé was taking a break under a mango tree at IRBAG when a frantic man ran up to him carrying an unconscious child. She'd been bitten by a snake, he said.

Once a venomous snake strikes, a race against the clock begins. Getting help can take hours, or days. By then it may be too late.

Baldé, then an entomologist studying vector-borne diseases, brought the 12-year-old into the clinic, but there was no hope. The institute had been a snakebite treatment center in the early 1900s, but by mid-century its focus had shifted. No one knew how to help the child.

"I was naturally shocked," Baldé says. It was a failure of duty to let people die like this.

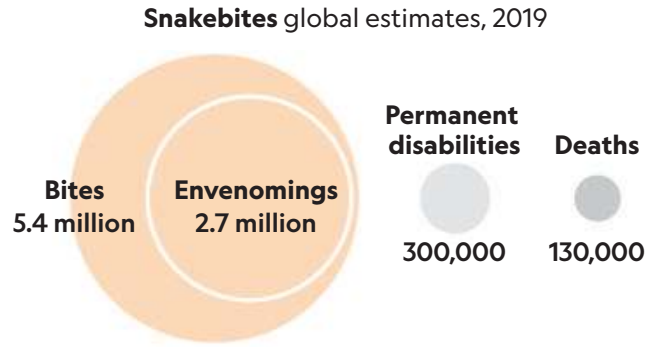
He vowed this girl would be the last such victim. He turned his focus from insects to snakes and began learning all he could about snakebites.

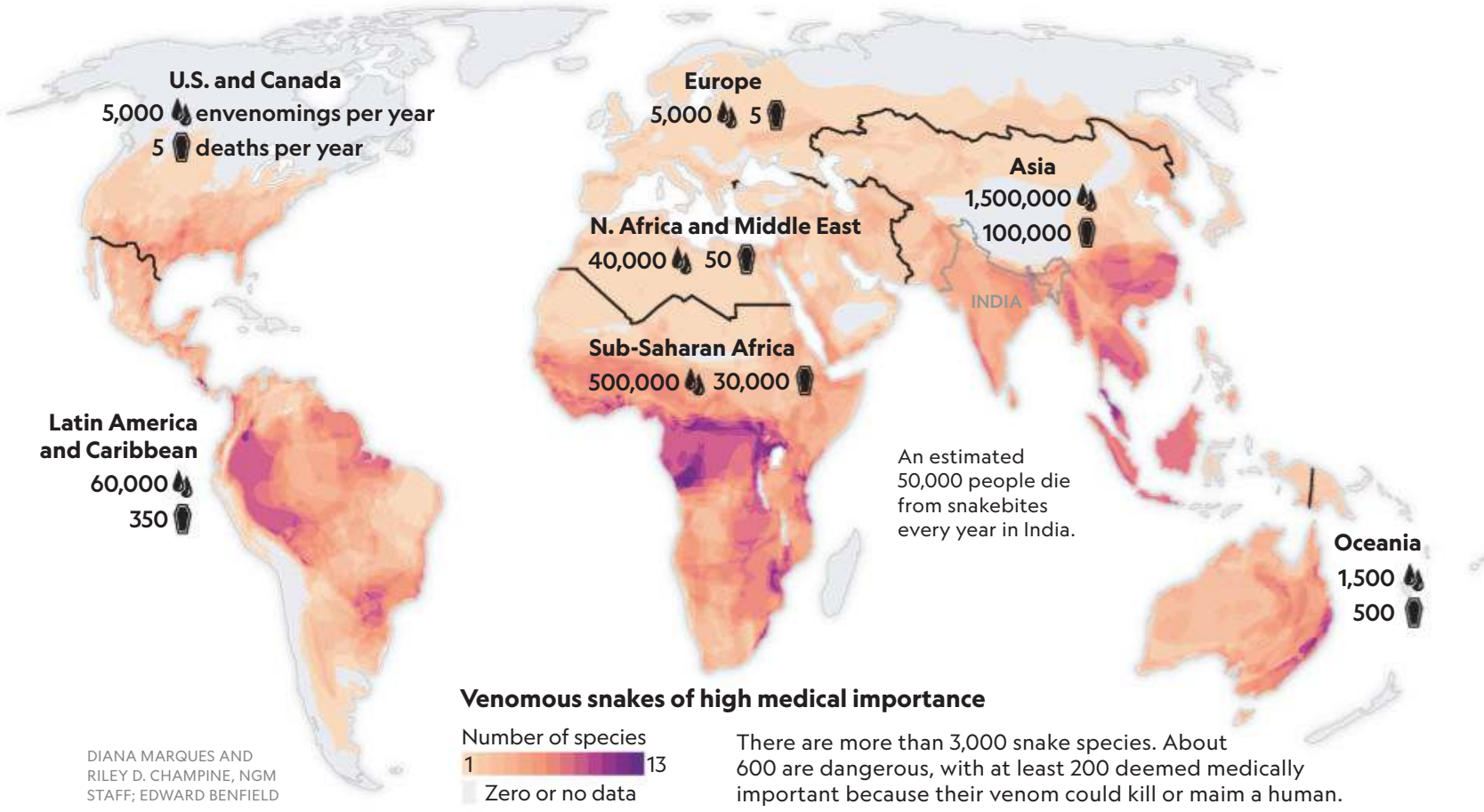
In his search for treatments through the years, Baldé, now a world-renowned herpetologist and lecturer on snakebites, has experimented with products available locally: Chinese-made pills and inexpensive injections of Indian-made antivenoms. He says the best he found was Fav-Afrique, an antivenom made by French pharmaceutical company Sanofi, which was effective against the venom of 10 of Africa's most dangerous snakes. But in 2014 Sanofi discontinued production because the medicine wasn't profitable.

Producing antivenoms is a long, expensive

Zones of risk

Venomous snakes are found around the world, but the people most at risk live in poor, rural regions of Africa and southern Asia, where access to treatment often is limited. Not all bites result in venom being injected (envenoming), but those that do can kill or permanently disable a person.





DIANA MARQUES AND RILEY D. CHAMPINE, NGM STAFF; EDWARD BENFIELD

There are more than 3,000 snake species. About 600 are dangerous, with at least 200 deemed medically important because their venom could kill or maim a human.

WHAT HEIGHTENS THE RISK

Rural location
People in rural areas, especially agricultural workers and hunters, are more likely to encounter a snake. Inadequate footwear or an insecure dwelling increases the risk of a bite.

Delayed treatment
Many seek only traditional medicine after a bite, or they may lack swift transport to a hospital. Any delays greatly raise the chance of disability or death.

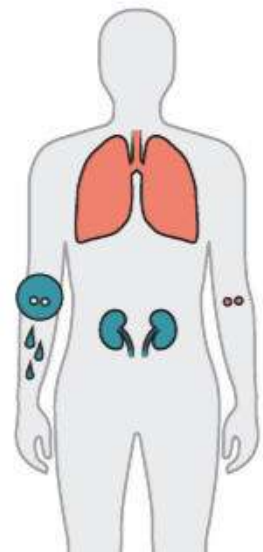
Limited health care
In poorer areas, medical facilities may not have health workers with the training or equipment to treat a dangerous bite. Many communities have no health facilities at all.

No antivenoms
Production is far below what's needed, and the right kinds of antivenoms often aren't available at clinics. Even if an antivenom is available, many victims can't afford it.

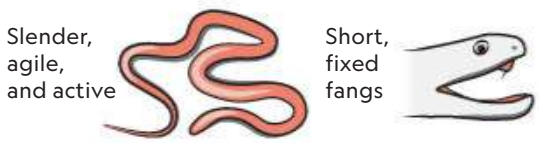
TWO BIGGEST THREATS

Four of the 18 snake families have species dangerous to humans, but the viper and elapid families are responsible for more than 95 percent of envenomations around the world.

Vipers
The venom of vipers such as rattlesnakes and adders can cause serious kidney damage and disrupt blood clotting and flow, to produce severe inflammation, hemorrhaging, and tissue death. Their venom typically kills within days.



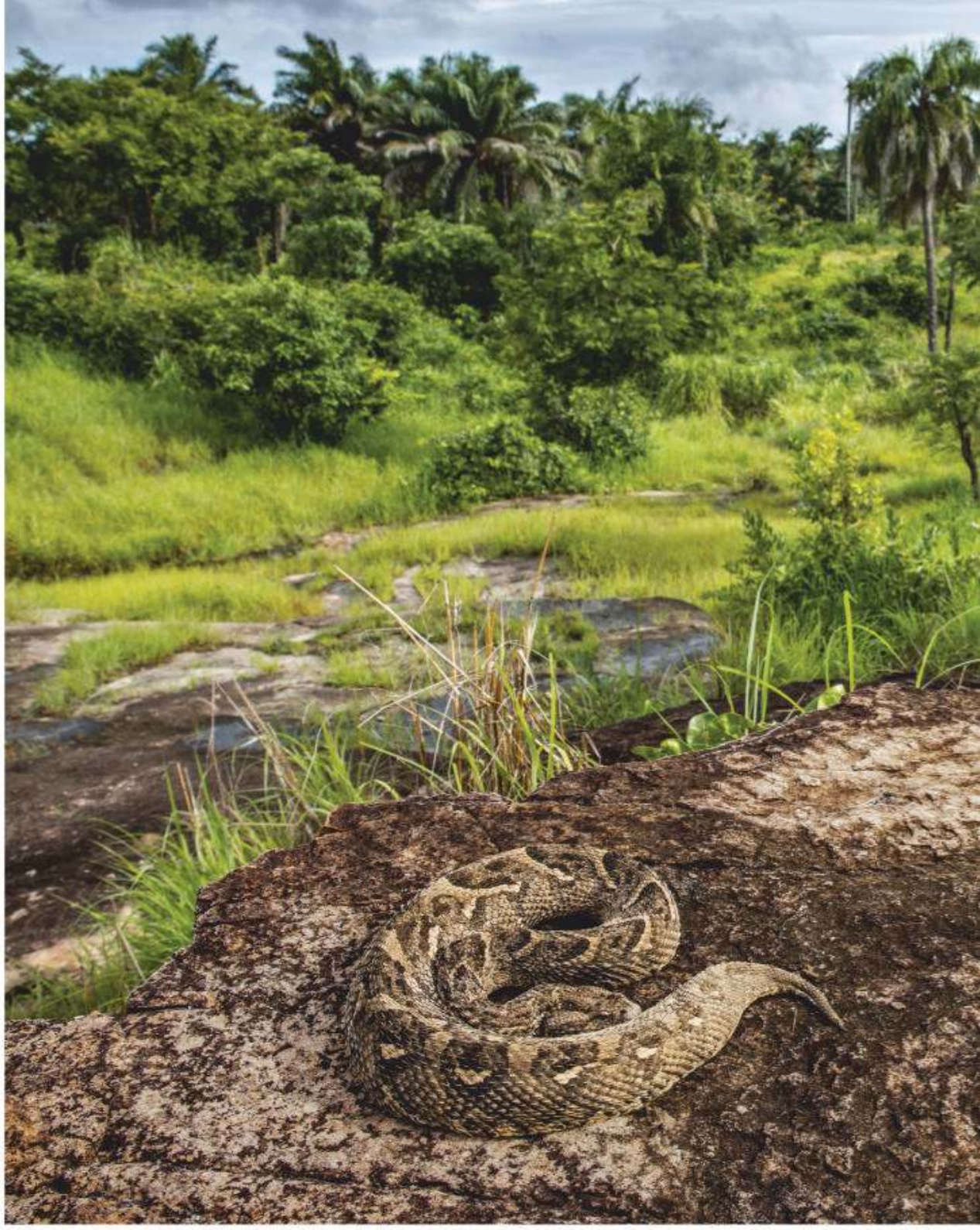
Elapids
Venom of elapids such as cobras, African mambas, and Australasian taipans can block the transmission of nerve impulses, paralyzing respiratory muscles and making it impossible to breathe. Their venom can kill within hours.



SOURCES: JEAN-PHILIPPE CHIPPAUX, FRENCH NATIONAL RESEARCH INSTITUTE FOR SUSTAINABLE DEVELOPMENT AND INSTITUT PASTEUR;

JORDAN BENJAMIN AND NICKLAUS BRANDEHOFF, ASCLEPIUS SNAKEBITE FOUNDATION; JOSHUA LONGBOTTOM, LIVERPOOL SCHOOL OF TROPICAL MEDICINE

Rémi Ksas, assisted by Antoine Planelles, extracts venom from a West African Gaboon viper for the French laboratory Latoxan, which supplies ingredients to antivenom manufacturers around the world. Venom can fetch thousands of dollars a gram.



A puff adder, one of Africa's most dangerous snakes, basks on a warm rock in Guinea. In 2017 the World Health Organization added snakebite to its list of neglected tropical diseases, spotlighting this health crisis to attract funding for research and treatment.

process, and because the vast majority of people who need them live in developing countries, such drugs are not big moneymakers.

Antivenom production requires actual venom. This comes from labs that may house thousands of snakes in captivity. They're milked about once a month for their venom. Depending on the species, venom can cost a pharmaceutical company up to several thousand dollars a gram.

Then the venom—in amounts too small to have deleterious effects—is injected into horses or other large mammals, whose blood develops antibodies. Blood is drawn, and lab technicians separate out the antibodies and purify them to make antivenoms.

Even with a high-quality antivenom, treating snakebites can be hit or miss: The chemical makeup of venom and its effects can vary from snake to snake, even within a species. "There's a huge lack of published data and research," says Jordan Benjamin, founder of the U.S.-based Asclepius Snakebite Foundation, which provides supplies and training to African clinics.

"Sometimes antivenoms that are supposed to treat certain species don't even work in some areas," says Colorado-based medical toxicologist Nick Brandehoff, the foundation's medical director. For example, "the puff adder's venom can change from one area to another. It's extremely complicated."

BY 2013, A COMPANY IN MEXICO, Inosan Biopharma, was marketing a new antivenom, one that can neutralize the toxins of at least 18 snake

species—more than almost any other available antivenom in Africa.

"You can treat even if you're not sure which snake caused the bite," Benjamin says. And it has an extremely low rate of severe side effects, which is a common problem with other antivenoms.

The drug, Inoserp Pan-Africa, also is advantageous in that it's freeze-dried. Not needing refrigeration is "a game changer," says Baldé, one of the first health-care providers to test it in the field.

For all its effectiveness, Inoserp is not being produced in sufficient quantities. There's a severe shortage of antivenoms more broadly: The number of vials in circulation is less than 5 percent of the one million to two million needed yearly in sub-Saharan Africa. And even if Inoserp were widely available, rural Africans—whose earnings may be no more than a few dollars a day—couldn't afford it. Hospitals and pharmacies might charge $80 to $120 or more a vial, and most snakebite victims require several vials.

Cheaper antivenoms are available but often are unreliable. "In several African countries we came across antivenom designed to treat bites from Indian snakes," says Jean-Philippe Chippaux, a tropical diseases expert at the French National Research Institute for Sustainable Development, who helped write WHO's snakebite strategy and has contributed to the development of antivenoms, including Inoserp.

"Governments should offer financial support," Chippaux says. "They should make antivenom cheaper so that people can be treated—the cost is a major problem."

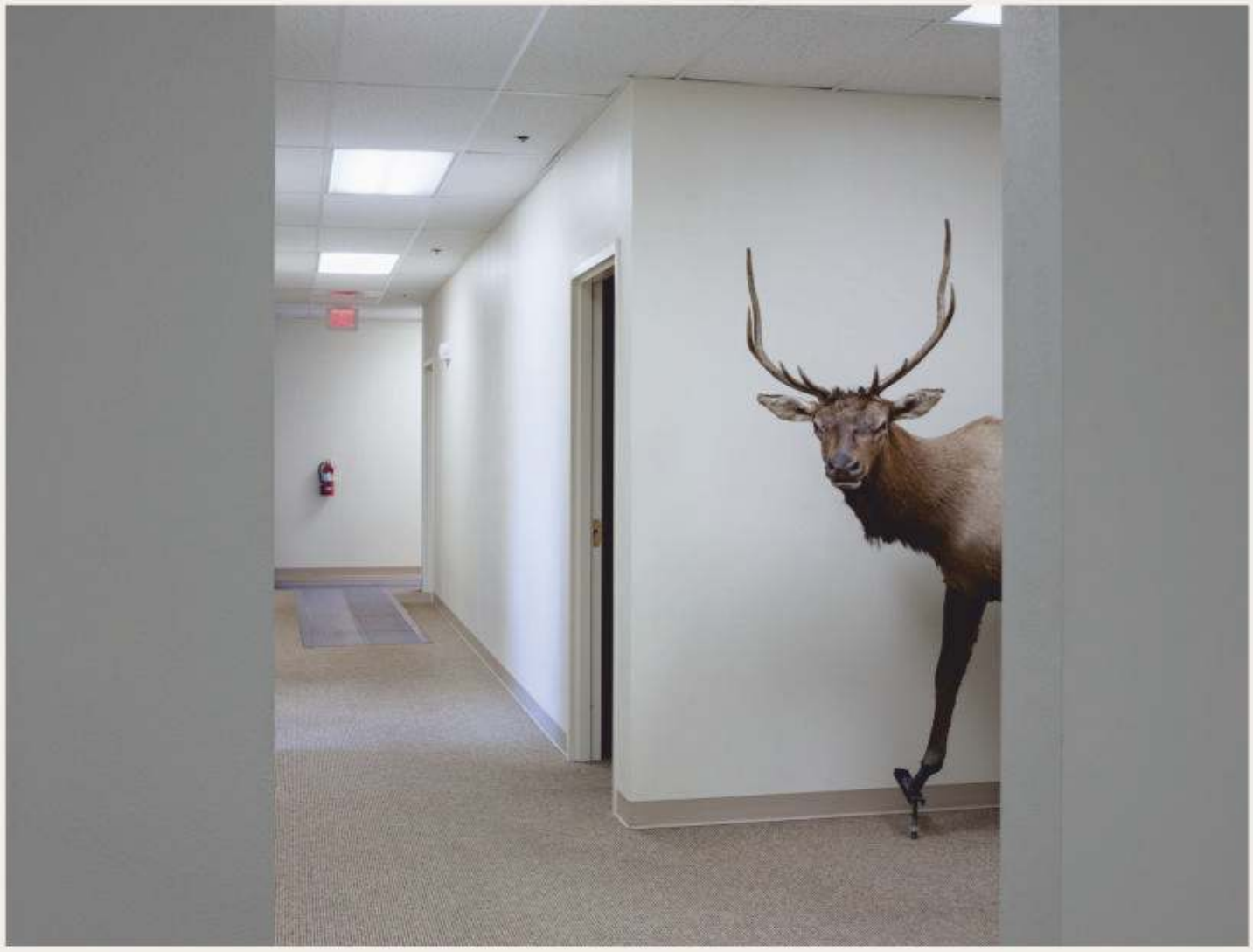
Inosan Biopharma is investing millions of dollars to ramp up production of Inoserp, hoping African governments eventually commit to buying sufficient amounts to counter the crisis. "So far, we're not making a profit on Inoserp," CEO Juan Silanes says. "Someone had to start investing, and we took that on, but we're proud of what we're doing because it's an important cause."

Other companies around the world also are researching new treatments, but nothing is as far along or as promising as Inoserp at the moment, Benjamin says. Some philanthropic organizations are stepping in where government support lags. Asclepius Snakebite Foundation, for example, provides free Inoserp and medical training to health centers in Guinea, Kenya, and Sierra Leone. The James Ashe Antivenom Trust buys antivenoms for hospitals in Kenya's Kilifi County so patients can get free treatment.

But, as Baldé says, preventing snakebites is better than having to treat them. Public awareness campaigns in Guinea and elsewhere echo what he tells his patients: Wear shoes when walking in places likely to have snakes, and use a flashlight at night.

"Snakebite has been a disease of the poor, so the policymakers don't care," Watamu Hospital's Erulu says. But he hopes WHO's new global investment in snakebite prevention will be effective. "Governments are going to be forced to look at it as a serious problem," he says. "That is a very, very important step." ▯

Thomas Nicolon is a photojournalist and National Geographic explorer who covers conservation in tropical rainforests. This is his first story for *National Geographic*.



INSTAGRAM

LUCAS FOGLIA

FROM OUR PHOTOGRAPHERS

WHO

A fine art and documentary photographer based in San Francisco

WHERE

Pinedale Regional Office of the Wyoming Game and Fish Department

WHAT

A Mamiya Leaf Aptus camera with a 55mm lens

To catch people hunting unlawfully in western Wyoming during the off-season, rangers from the state's Game and Fish Department occasionally conduct sting operations. They position a taxidermied elk in mountain valleys and wait out of sight for someone to shoot at it. This elk was on its day off in the hallway of the department's Pinedale Regional Office when Foglia took this photograph. It's an ideal image for *Human Nature,* Foglia's recent exhibition and book about people's interactions with wild spaces.

This page showcases images from National Geographic's Instagram accounts. We're the most popular brand on Instagram, with more than 210 million followers; join them at **instagram.com/natgeo.**

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Great Green Macaw
(Ara ambiguus)

Size:
Body length, 85 - 90 cm (33.5 - 35.4 inches)
Weight:
1.3 - 1.4 kg (2.9 - 3.1 lbs)
Habitat:
Humid lowland evergreen and deciduous forests
Surviving number:
Estimated at fewer than 2,500 mature individuals

Photographed by Phil Savoie

WILDLIFE AS CANON SEES IT

Brilliant. The great green macaw loves beach almonds, but hates the bitter taste of the outer layer. The solution? Use leaves as tools to scrape the bitter part away. This clever macaw also depends on the seeds of mountain almond trees, and travels long distances to follow their fruiting. It eats a variety of seeds, making short work of hard shells with its large beak. But it can't crack the problems of habitat loss, hunting and food scarcity. What does the future hold for this beautiful bird?

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.


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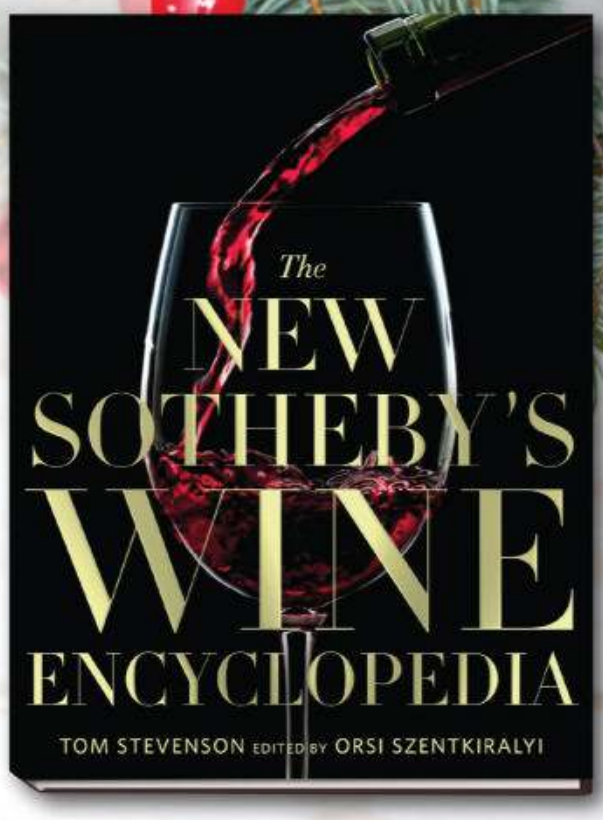
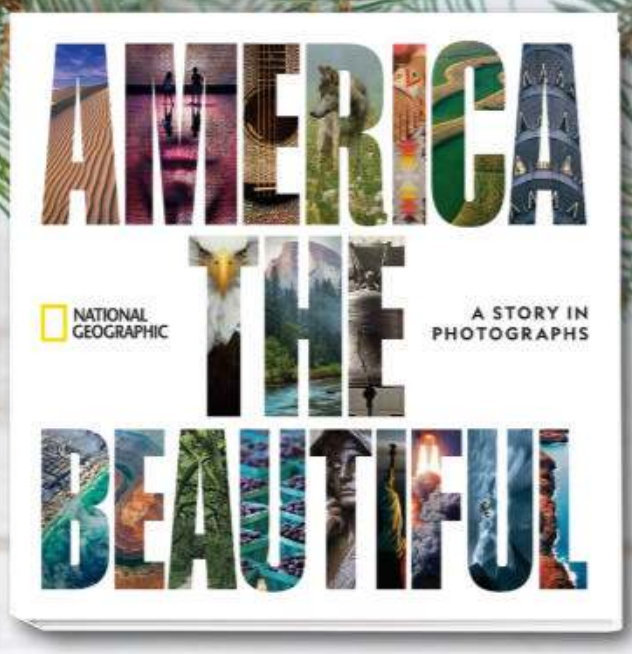
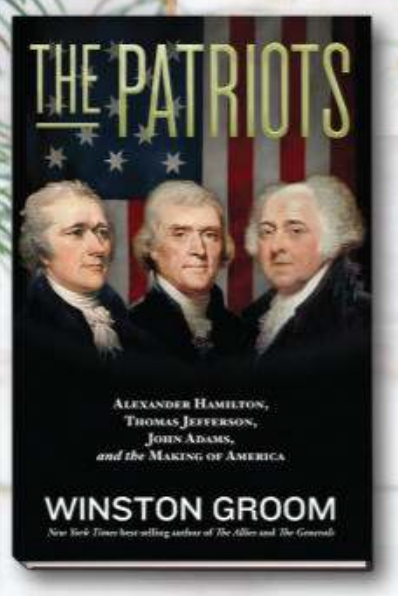
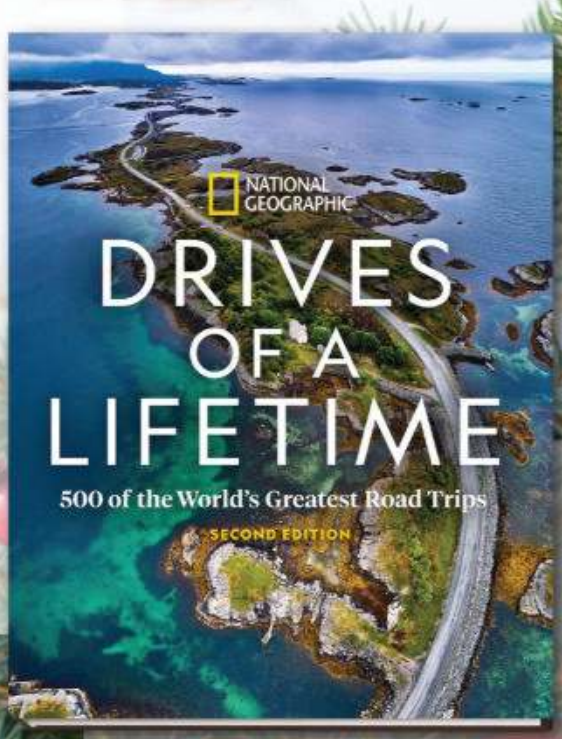
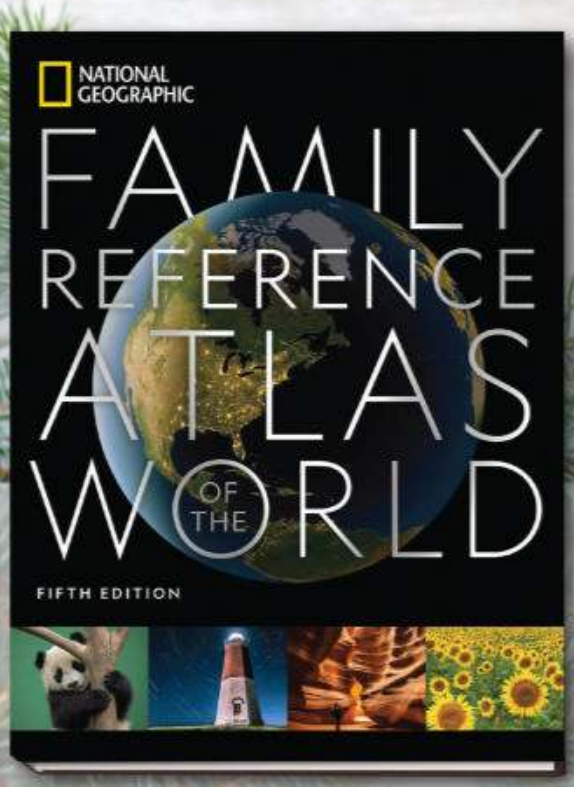
GREAT HOLIDAY GIFTS

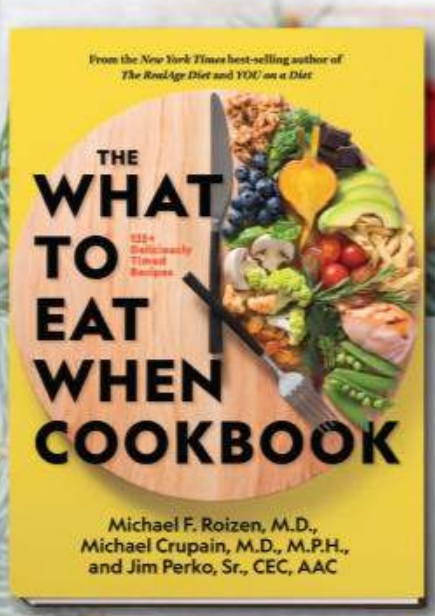












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